HORIZON STE

Final Country Reports

Deliverable 2.4

WP 2 & 3: **Re-launching STE Industry in Europe / R&I Impact Maximisation**

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HORIZON STE

Implementation of the Initiative for Global Leadership in Solar Thermal Electricity

DELIVERABLE FACTSHEET

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ESTELA, European Solar Thermal Electricity Association

Contributing Partners

CIEMAT, Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas

ENEA, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

DLR, Deutsches Zentrum Fuer Luft - Und Raumfahrt EV

METU, Middle East Technical University

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About the Project

HORIZON-STE is a Horizon 2020 funded project aiming at supporting the Implementation of the Initiative for Global Leadership in Solar Thermal Electricity (STE), also known as Concentrated Solar Power (CSP), which was launched by the European Commission and adopted within the Strategic Energy Technology Plan (SET Plan) of the European Commission.

Since more than a decade, Europe's Solar Thermal Electricity sector holds a worldwide technology leader until its further development abruptly hindered in Europe. To unlock this situation, the European Commission has launched a dedicated Initiative – Initiative for Global Leadership in Concentrated Solar Power focusing on 2 targets: a cost reduction target and an innovation target, in order to keep STE's global technology leadership and rebuild a home market in Europe.

Acting as competence centre of the Implementation Working Group within the Strategic Energy Technology Plan (SET Plan) of the European Commission, the overall goal of HORIZON-STE is to support the execution of the Implementation Plan regarding both STE Research and Innovation lines as well as First-Of-A-Kind projects that will help steer countries through political, legislative, and institutional shortcomings linked to various national policies concerning solar thermal electricity. Much of the focus centres on improving procurement of manageable RES and increased public funding for STE research.

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INTRODUCTION

Description of task

The Integrated Country Report is part of the Work Package 2 "Re-Launching STE Industry in Europe" for which ESTELA is task leader. As a reminder, the overall objectives of WP2 are labelled as follows in the initial proposal:

> "Assessment of the conditions for replicating in European countries the commercial cost levels (<10 €cts/kWh) already achieved by the industry on CSP/STE world markets (financial conditions, type of auctions, contribution of innovations delivered by R&I) as one of the objectives of the Initiative and its Implementation Plan."

This deliverable is the outcome of the task 2.4, corresponding to "Integrated country/regional reports (combined R&I and industry perspective)". The overall objective of this task was double:

- To first produce a general overview of the energy strategies embraced by each country of focus and understand the needs and expectations of political stakeholder.
- To then provide industrial and political stakeholders with ad hoc propositions of STE uses to meet the strategy and system requirements.

This task lasted from M8 to M40 and was continuously enriched, following the path of the country analyses. First focusing on individual cases, the compilation of countries highlights potential cooperation and/or complementary needs between Member States. It is based on the Report on Stakeholder Mapping, delivered in M7 (D2.1) which gave a framework to the country approach. Each country of focus in WP2 was an object of a draft country report which gathered, from the industry perspective:

- A summary of the country's needs.
- The framework conditions and power plant basic configuration and siting vs other options.
- The CSP added value (system value and macroeconomic value for the country).

Based on this, Deliverable D2.3, "Integrated Country Report" combines industry and R&I perspectives, based on D2.2 "Draft Country Report Industry Perspective". It displays findings in terms of policy recommendations and solutions to improve funding mechanisms and industry/trading opportunities.

This integrated report is a key pillar for the writing of the Final Report. It will serve as a reference in the construction of strategic solutions to create the necessary conditions for further development of STE while matching countries' concerns.

1 Chapter 1: Turkey

Turkey is the first country to be under the scope of HORIZON-STE. The following chapters will describe the work undertaken in Turkey and analyse the challenges and opportunities met in the country.

1.1 Structure of the document

The deliverable D2.2 "Draft Country Report" is presented here in its broader version (D2.3) as an "Integrated Country Report". It aims to provide a first global and structured approach of the different country profiles regarding potential interest to STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2 and WP3 concerning:

- The expressed need for manageable RES energy by each country of focus and their respective strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.
- The construction of a defined framework for funding and its reception by relevant audiences.
- The evaluation of performance of the funding frameworks.

Section 1.2 summarises the tasks which were carried out, both on the R&I (1.2.1) and industrial (1.2.2) sides. This gives an overview of the intelligence collected and of the final key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Proposition of a reshaped funding framework based on feedback from stakeholders and the Implementation Working Group (IWG).
- Dissemination of information about the funding opportunities and impact evaluation.
- Meeting with relevant stakeholders, i.a. at Ministry, TSO and Regulatory Authority levels, as well as key players from local industries and civil society.
- Brokerage events and joint industry-R&I national events.

A deeper analysis of the context of Turkey is provided in 1.3, first for the research part (1.3.1) and then for the industry (1.3.2). Each of these sections provides a global overview of the different factors influencing the development of funding and commercialisation of STE applications. More precisely, it aims to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Turkey.

Based on these observations, key findings are drawn in part 1.4, for both research and industry. They highlight encountered challenges and existing opportunities and finally draws a picture of the potential synergies between R&I and industry structures.

Last but not least, section 1.5 suggests strategic actions to continue opening doors for STE in Turkey, from a research and then industrial point of view. It finally offers an overarching approach to further support the development of STE in Turkey, combining R&I and industry perspectives to offer thorough advice.

1.2 Summary of undertaken activities

1.2.1 R&I-Methodology

To understand the current situation in Turkey in both global context and European context, we made a qualitative analysis of expert interviews and quantitative analysis of bibliometrics.

In **qualitative analysis**, the motivation is to understand the current situation in CSP/STE Research & Innovation and Industrialization & Marketization in Turkey from key experts' perspectives. The technique used was qualitative semi-structured interviews. These interviews were conducted with the key experts in the sector since the primary sources of data were the key actors' perspectives, experiences, approaches, beliefs and functions (Patton, 2002). The sampling strategy was "purposeful sampling" to pick the information rich cases in the population, and snowball sampling to go to the corresponding experts referred by the former informant (Patton, 2002; Flyvbjerg, 2006).

We conducted (in Turkish) 14 semi-structured interviews with the researchers and professors at universities and research centres (5 interviews); company owners, entrepreneurs, consultants and service providers from industry (5); bureaucrats and regulators in public sector (3), and non-profit organization (1) on face-to-face base in Istanbul and Ankara, and via phone calls & video conferences. We completed interviews between November 2019 - January 2020. Also, we accompanied ESTELA Team's meetings in Ankara and exploited the opportunity of benefiting from the discussion in these meetings. We used a general interview guide which included six sections of

- Introduction and Actor Profile (understanding of the global energy and renewable energy situation per stakeholder).
- Current Situation (to understand the global landscape of Turkey regarding energy policy).
- Opportunities and Threats for Diffusion of CSP/ STE Technologies (to understand the diffusion process).
- Market (to understand the marketization and industrial dynamics).
- Policy (to determine the potential needs for manageable RES and the strategy developed by the government and the main stakeholders regarding energy and renewable energy).
- Future Expectations & Foresights (Potential challenges and foresight about the CSP/STE technology development & deployment).

Each interview is recorded and verbatim transcribed by the project assistants. The raw data text is analysed, the findings are presented by grouping the quotations and derivation in eight different categories, and the main findings are reported by referring to these categories.

In **quantitative analysis**, the motivation is to measure the research performance in CSP/STE Research Field. Bibliometrics, by OECD Glossary of Statistical Terms[1], is defined

[1] See: https://stats.oecd.org/glossary/detail.asp?ID=198

as the "statistical analysis of books, articles, or other publications". The bibliometric analysis includes[2]

- collecting data on scientific articles and publications classified by authors and/or by institutions, fields of science, country, topics, keywords, titles etc., to construct indicators for measuring academic research.
- to identify & understand the dynamics of research networks, and to map the development of new research field. Bibliometric research is performed through the uses of indexes like Web of Science or Scopus.

In this study, a small panel that consisted of METU Horizon STE Project Team identified keywords that were relevant for Concentrated Solar Power and Solar Thermal Energy Research. The keywords to grasp the main frame in the Turkish Case are "concentrated solar power", "concentrating solar power", "solar thermal electricity", "solar thermal", "thermal energy storage", and "solar heat for industrial process". Using these keywords, we conducted a search in the Web of Science™ Core Collection database to create our data set of Turkish Researchers.

Web of Science is a website and research engine that delivers publication and research measurement indicators (such as citations) data from different disciplines[3]. We scanned Web of Science (WOS) Database by searching our keywords in the TOPIC Area[4] for Turkish Case. By this search, you can find the articles which have the specific keywords in "Keywords", "Title" and "Abstract" sections of the article. As of May 2020, our search retrieved 483 publications indexed in the Web of Science ™ Core Collection that had at list one co-author affiliated with a Turkish university or research institute. Of the 483 publications, 429 were tagged as articles and 57 as proceedings.

Visualization of connections between authors, institutions and countries are constructed using VosViewer (http://www.vosviewer.com) and CiteSpace (http://cluster.cis.drexel.edu/~cchen/citespace) visualization tools, which are freely available software for bibliometric studies. The results of the bibliometric study are described by using these graphs and visual maps (Aydınoglu & Taskin, 2018).

List of activities	Timeline
Background research	Phase 1 June – October 2019
Aim: To collect relevant information to understand better CSP/STE Landscape in Turkey, the current situation, potential development paths and challenges for the development of CST & to define and determine the main actors and stakeholders in the sector for stakeholder mapping and country report interviews.	

[2] See: https://instr.iastate.libguides.com/c.php?g=49332&p=318077

[3] See: https://clarivate.com/webofsciencegroup/solutions/web-of-science/ *(Last access: May 05, 2020)*

[4] *You can make article search from WOS Database by using Topic, Title, Author, Publication Name, Year Published, Funding Agency etc.*

List of activities	Timeline
Desk research:	Collect of information based on available information on official websites (e.g.: Ministry of Energy and Natural Resources [MENR], TEIAŞ, EMRA, etc.), academic studies or reports by consultancies, direct contacts with the experts.
Identification of Contacts for Stakeholder mapping:	Analysis of the specific relevant departments and actors for each identified target group to gather information and contact details of the stakeholders, listing the stakeholders and gathering contact information and consent to be interviewed.
Visits	Phase 2: November 2019 – January 2020

Aim: To generate data through expert interviews

- to determine needs in the renewable energy sector in Turkey
- to have feedback on scientific, political, economic and social factors affecting development and diffusion of CSP/STE Technologies in Turkey
- to understand the current and future energy strategies regarding energy security and renewable energy sector in relevant framework conditions

Description of the Stakeholders:

Researchers	- Prof. Dr. Halime Ömür Paksoy from Cukurova University, Dep. of Chemistry, Turkish Delegate& Representative of International Energy Agency Energy Conservation through Energy Storage Technology Collaboration Program (IEA ECES TCP). - Prof. Dr. Uner Colak from Istanbul Technical University, Institute of Energy, Head of Renewable Energy Division. - Prof. Dr. Hakan Erturk, Bogazici University, Dep. of Mechanical Engineering, Head of Thermal Energy Systems Laboratory. - Prof. Dr. İskender Gökalp, TUBITAK 2232 Leader Researchers Grant Programme holder, hosted by METU Mechanical Engineering Dep. And Emeritus Professor of French National Centre for Scientific Research/CNRS. - Prof. Dr. Pınar Menguc from Ozyegin University, Center for Energy, Environment and Economy
Public Sector.	- Head of Planning and Investment Department of TEIAŞ (TSO of Turkey) - Head of Department of Energy Efficiency and Environment / Energy Advisor to the Minister, MENER - Head of Renewable Energy Department of Energy Market Regulatory Authority
Private Sector/ Companies	- TEKFEN Co (investors in CSP /STE Energy Solution and SHIP R&D activities, project team member of H2020 Projects in CSP / STE) - Zorlu Holding (investors in CSP/STE Energy Solution and SHIP R& D activities, investors in a geothermal power plant in Turkey)

List of activities	Timeline
	- Emerson Co. (International Co. for Automation Solutions of Power Plants including CSP / STE & enter Turkey to exploit the opportunities in CSP Sector in Turkey and MENR Region) - Serdar Erturan, Entrepreneur of the First CSP Plant in Turkey (Greenway Co. And NYU) - GKE Energy (having R&D Centre for Energy Solutions in Turkey, Consultant and service provider for energy investments in Turkey and MENR Region)
NGOs	- SHURA Transition Centre (An NGO directly involved in Transition of Energy Sector and Sustainable Solutions to Energy Problems in Turkey in the international context)
BIBLIOMETRIC ANALYSIS	**Phase 3:** February 2020-May 2020
Aim: To collect data for scientific research base in CSP/STE by measurement of research performance through publication search.	
Description: By using relevant keywords (approved by the experts), full-text article searches in the Web of Science™ Core Collection and reporting the data by using visualization and graphical tools. Data Set: Publication search by using "concentrated solar power", "concentrating solar power", "solar thermal electricity", "solar thermal", "thermal energy storage", and "solar heat for industrial process" keywords to understand Turkey's research performance (as of May 2020, app. 500 publications are found). *Further Step: Publication search in European Context which provides current situation analysis and comparative analysis for research performance of EU countries involved in the project & CSP / STE Research by using a set of keyword encompassing a wide range of research activities in CSP / STE (such as Solar Thermal Storage and Thermal Energy Storage)*	

1.2.2 Industry

1.2.2.1 Foreseen activities and implementation challenges

To favour a sustainable launch of STE in studied countries, ESTELA designed a general process unfolding in three steps:

PHASE 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and Turkey's strategies on its procurement / possible changes in the relevant framework conditions
Encountered challenges	– To find the right interlocutor – Important information only available in Turkish – Low answer rate to interview request
Applied mitigation	– Help from METU (local partner) to identify relevant stakeholders with whom they are already in touch – Simplified translation of official documents from Turkish to English

	– Help from METU to collect consent from potential interviewees
PHASE 2	
BROKERAGE EVENT - INDUSTRY	
General aim	Assessment and presentation of potential industrial solutions using CSP/STE
Encountered challenges	– Gathering key stakeholders from industry sector – Matching research and industry potential
Applied mitigation	– Combined brokerage event Industry – R&I – Help from METU to identify relevant research projects matching industry reality and policy needs – Organisation of sessions interweaving capacities and existing activities
PHASE 3	
JOINT NATIONAL EVENT – INDUSTRY AND R&I	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	– Burst out of international public health crisis – Delay in the organisation of the event
Applied mitigation	– Rescheduling

1.2.2.2 Carried out activities

LIST OF ACTIVITIES	TIMELINE
BACKGROUND RESEARCH	Phase 1 Oct.-Dec. 2019
Aim: To collect relevant information to better understand the energy landscape in Turkey, the potential challenges for the development of STE and the needs of the country	
Description Desk research: Collect of information based on available information on official websites (e.g.: Ministry of Energy and Natural Resources [MENR], TEIAŞ, EMRA, etc.), academic studies or reports by consultancies Stakeholder mapping: Analysis of the specific relevant departments and actors for each identified target group Exchanges with HORIZON-STE Turkish partner (METU) on relevant contacts and existing knowledge of the local situation	
PRELIMINARY VISITS	Phase 1 January 2020
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable renewable energy sources (RES), the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions	
Description TSO: Meeting with representatives of TEIAŞ including the the Head of Foreign Affairs Department, Head of Planning and Investment Management Department and the Head of R&D Management Department MENER: Two meetings Meeting with the Head of DG Renewable Energy and two other representatives from the DG, including from the Solar Energy Unit	

LIST OF ACTIVITIES	TIMELINE

Regulatory Authority: Meeting with the Head of Department of Energy Efficiency and Environment / Energy Advisor to the Minister

Meeting with the Head of Electricity Market Department and members of other units, including the one in charge of the (upcoming) regulation on hybrid generation

PHONE INTERVIEWS	Phase 1 Feb.-March 2020

Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of Turkey's energy strategy and potential need for manageable RES

Description

Industry: Two interviews to gather insights into market conditions for the development of innovative technologies in Turkey, to capitalise on existing assets and favour their development, to optimise investment and return on investment

Interview with the founder of Greenway CSP in Turkey

Interview with the Department for Environment and Energy of the Istanbul Chamber of Commerce

Finance institution: Interview with the actors responsible for Project Financing and Credits and Project Finance Structuring, to understand the financing framework in Turkey for innovative projects, to determine the conditions to facilitate access to funding, to foster high relevance between funding and market opportunities

Civil Society: Interview with the Marketing Director of the Energy Transition Centre to outline the existing potential in Turkey for the development of CSP/CST technologies, to facilitate synergies between research and commercial realisation of projects

WORKSHOP	Phase 2 February 2020

Aim: To have a broad overview of STE perspectives in Turkey through existing and potential solutions using STE, from both the R&I and industry sides.

Description

Participation in the $ODAK_{2023}$ project kick-off event. 95 people attended the event. 19% from industry, 65% from university, 5% Funding Agency, 4% Government, and 7% from other.

It has the purpose of "creating a common national vision for CST in Turkey in 2023". The workshop aimed to provide an open forum to start defining this common national vision and to promote collaboration between national stakeholders. The audience and speakers were composed of actors from the R&I and industry, who are working on different applications of STE, as well as of policymakers.

ESTELA presented HORIZON-STE and the first outcomes of its research in the country, insisting on the necessity to embrace a two-fold approach when striving to further deploy STE/CST. More specifically, ESTELA enhanced the role of policymakers to provide a favourable environment for R&I and industry to build synergies and grow further.

This event was considered as a "brokerage event" and as a dissemination event of the HORIZON-STE project. Although the initial approach for the "brokerage events" was to include only actors from the industry and key national stakeholders, it proved valuable execute it in this joint manner (similar to what was originally described as a "joint national event"). The event was combined with a technical visit to the research facilities at METU and ODTU GUNAM. This technical visit included tours and briefs about the research facilities of ODAK: Mechanical Engineering, CST Laboratory Facilities, ODTU GUNAM Pilot PV Line, METU's Department of Environmental Engineering Laboratories, METU's Membranes for

LIST OF ACTIVITIES	TIMELINE
Energy and Water Laboratory in Chemical Engineering, METU's Central Laboratory and METU's Wind Energy Research Center-RUZGEM.	
NATIONAL EVENT	Phase 3 April 2022
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the development of STE in Turkey. To focus on possible synergies and macro-economic value. Description Thanks to METU, ESTELA secured an afternoon slot at the SolarEx Fair of Istanbul to organise round-tables and panels for all relevant stakeholders involved in the STE sector or energy policy at large. In addition to local stakeholders, ESTELA planned to involve European industries, to exchange views on potential cooperation and development of business in Turkey. Originally planned in April 2020, the event was postponed by the Turkish authorities due to the Covid-19 pandemic. After the slow recovery from the Covid-19 pandemic, the Joint Industry and R&I National Event in Turkey took place on 07 April 2022 in a hybrid format, online via Zoom and Youtube and in person at the seven-part conference jointly co-organised with the aligned EU H2020 SolarTwins project in the framework of the International Istanbul Solar Energy and Technologies Fair (SOLAREX) at the Gold Conference Room, Istanbul EXPO Center, Instabul, Turkey. The main conclusions and highlights of the event will be reported in the Deliverable 4.7 "Proceedings of the Joint Industry and R&I Events".	

1.3 First observations

1.3.1 R&I landscape:

In qualitative analysis, we conducted fourteen interviews with *industrial stakeholders* such as company owners, investors in technology development activities for SHIP applications, service supplier and entrepreneurs; *researcher*s conducting cutting edge research in the CSP / STE Research and Sustainable Transitions in Energy Sector; high level *bureaucrat*s from the public sector at Ministry of Energy & TSO and a civil society representative. We try to understand existing political, legislative, institutional, scientific, social and economic environment in Turkey for development, diffusion, industrialization, commercialization and implementation of CSP/STE Technologies. For this purpose, we examined the interview transcriptions and grouped quotations and derivations under six headings to describe and report the main findings. These groups are:

1. Technology Development & Domestic Production.
2. Industrialization of the research.
3. Implications of CSP / STE Technologies (Hybridization and SHIP).
4. Storage and Integration of CSP to Energy Sector.
5. Supports & Incentives for Development & Diffusion.
6. Political & Legislative Framework.
7. Problems and Threats.
8. Future of the Technology & Foresights.

For current situation of Turkish Energy Sector and CSP/STE Technologies and Implications in the sector, referring to above mentioned categories, we can derive following main findings by using the briefs of information given by the interviews:

- ✓ *There is robust research infrastructure & qualified cutting-edge research in the area for technology development and domestic production of the equipment*

In Turkey, the research capabilities and skills in basic science (such as Physics and Chemistry) and Engineering Departments (Mechanical, Electrical & Electronics, Environmental and Chemistry Engineering) are very strong, the researchers are experienced, and well-integrated to global and European context via strong link. Also, Turkish Industry has long history in energy technologies and has capabilities to make domestic production. Domestic production and in-house technology development and implementation are very critical for Turkish Energy Sector as being targeted by the National Energy Strategy based on "domestic production, energy security, decreasing import dependency and foreseeable markets".

- ✓ *Commercialisation and industrialisation of the research*

The links between companies and the research conducted in universities are loose. Most probably, this is due to Turkey's R&I eco-system especially in CSP /STE Research being weak. A new trend in the Turkish energy landscape started approximately in the 2000s due to increasing energy demand, increasing import dependency for fossil fuels, debates about energy security and self-sufficiency, and a desire to supply energy needs quickly.

This trend brought motivations towards using renewable energy sources in energy generation more than before. As the saturation in wind energy and PV solar is experienced, new technologies and sources will come to fore (as geothermal, concentrated solar thermal, biomass….). If this new trend can be absorbed by the private sector (the leading investors in energy generation in Turkey) as in case of PV after 2015; CSP /STE would be a new rising trend in Turkey. Here commercialisation of the research is significant since this is a new sector and directing it in the right direction with robust and reliable grounds would be the key to success. For this purpose, university-industry relationship and its nature would be one of the critical points in R&I part of the report.

- ✓ For companies Solar Heat for Industrial Processes (SHIP) is promising and variation of i*mplications for CSP / STE Technologies including hybrid solutions and power plants are the promising areas for development and diffusion of CSP / STE Technologies.*

Here the main emphasis is on go small and supply the energy needs of companies by their facilities and sources. SHIP is crucial for the companies who can integrate it into their production facilities, and which have available and appropriate location for such SHIP investment (both in terms of DNI and region of production). Energy cost is increasing day by day in Turkey. Electricity is becoming more expensive even in industrial production, which was subsidized at high levels in the past, but not anymore.

- ✓ CSP is a solution for the problems of renewable energy storage and supply security

Being a solution to storage and supply security problems is an essential advantage of concentrated solar power technologies and not very well known or appreciated. This is mainly because of not knowing the technology completely. Diffusion of technology and increasing awareness about the benefits of this technology are very critical. New suggestions should be made, and new models should be built to promote this diffusion. Complementary and hybrid solutions to the energy problem are preferred. Hybridization rather than the individual CSP power plants are the key for diffusion.

- ✓ Integration of both industry and university to EU Research Networks

EU Research networks are secure, and Turkey's inclusion in these networks are becoming stronger. This brings natural boundaries (and also constraints) for Turkey's research activities. Again, this well-structured integration can be exploited to build the concentrated solar power sector in Turkey and transfer the knowledge, technology and industrialization base to neighbour countries through Turkey. Also, industrial integration is very critical, and companies in Turkey have that vision to integrate into European networks.

- ✓ There is an established Political and Regulatory framework for Renewable Energy in Turkey. However, the Support Mechanisms such as YEKA and YEKDEM should be updated to support diffusion. Additionally, for secure and progressive technology development and implementation, there is a Need for political stability for investment decision

In Turkey, political structure and the regulatory documents are established, following the new trends and needs in the sector. Politicians can regulate the industry with close relations and continuous updating after following the links. This is a result of structural change in the role of the state in the energy sector. This brings flexibility in connections.

On the other hand, policy makers cannot respond quickly to urgent needs to provide sustainability of the system. However, this is still an experimentation period and structural change still continuous. This would be turned to an advantage for CSP/STE to exploit the new opportunities in the energy sector with changing consumption, production and regulation patterns.

For the energy investments in Turkey (especially coming from abroad) political stability in the country is seen very important. This can be promoted by the direct motivation of political landscape towards RE and CSP/STE. The investors (both foreign and domestic) are looking for support for this new technology. We are also trying to build this support via networking, lobbying, being a strong participant to EU Research Networks (both funding programs and EUSOLARIS ERIC).

- ✓ For future of the technology, Energy Mix including Renewable Energy and SHIP implications would be main focus.

Energy Mix is directly related to Turkey's primary energy policy of energy security and decreasing import dependency. To exploit domestic renewable energy sources, hence decreasing import dependency energy mixing solution and SHIP implications in local industrial production facilities would be the main focus. Since Turkey has a robust research base and high application and implication potential for this technology, CSP is a low hanging fruit for both researchers and industrial partners.

In quantitative analysis part, namely "the bibliometric analysis of Turkish scholarly research on CSP", we generated data to understand the general landscape in CSP research in Turkey. A small panel that consisted of the METU Horizon STE Project Team identified keywords that were relevant to the project: "concentrated solar power", "concentrating solar power", "solar thermal electricity", "solar thermal", "thermal energy storage", and "solar heat for industrial process". On May 6, 2020 we conducted a search in the Web of Science ™ Core Collection database to create our dataset. Our search retrieved 483 publications indexed in the Web of Science ™ Core Collection that had at list one co-author affiliated with a Turkish university or research institute. Of the 483 publications, 429 were tagged as articles and 57 as proceedings. The CSP / STE research started to take off in the early 2000s and even though there were some setbacks, the overall trend demonstrates that Turkish researchers are publishing more CSP related research – in two decades it reached to more than 50 publications per year (Figure 1).

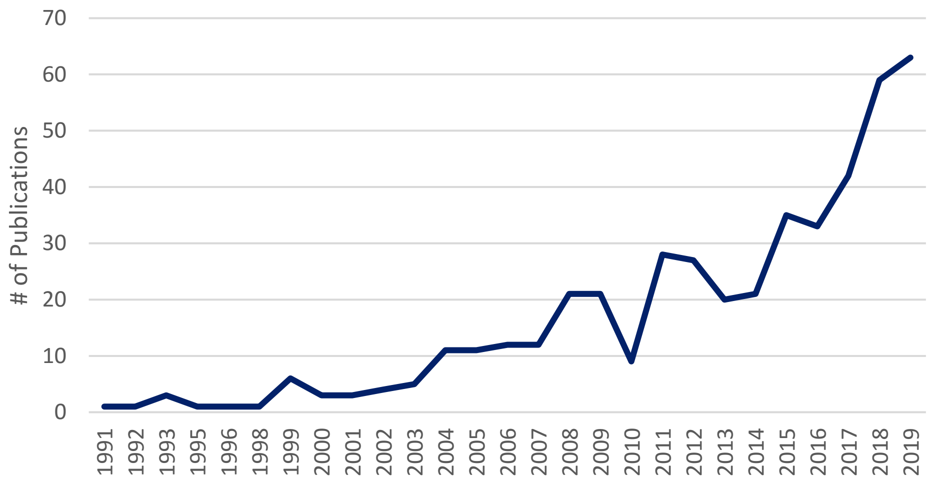

Figure 1: Annual number of publications

Figure 2 provides the name of the most scholarly productive researchers in Turkey. Here the indicator is the number of publications per author[5]. Ahmet Sari (Karadeniz Technical University & King Fahd University of Petroleum Minerals) with 99 publications on top of the list. Cemil Alkan (Gaziosmanpasa University) with 58, Kamil Kaygusuz (Karadeniz Technical University) with 40, Ali Karaipekli (Cankiri Karatekin University) with 35, Alper Bicer (Gaziosmanpasa University) with 34, and Halime Paksoy (Cukurova University) with 25, and Yeliz Konuklu (Omer Halisdemir University) with 24 publications are among the other researchers in the list. There is one name that is not affiliated with Turkish organizations, Ibrahim Dincer of Ontario Technical University; however, as he is listed as a coauthor in 25 of the 483 publications, his name pops up in the treemap.

Figure 2: The top-25 co-authorship Treemap

[5] *The impact of the paper is not evaluated here in this analysis.*

In Figure 3 the co-authorship collaboration networks are visualized, with each network being identified with a different colour. As communicated by Figure 3, the most active authors (Halime Paksoy, Ahmet Sari, Cemil Alkan, Kamil Kaygusuz) are at the centre of a small network, and these smaller networks are linked to form a larger and dominant network. The authors outside this dominant network work in smaller and independent networks. In conclusion, the co-author collaboration networks can be described as consisting of a main network containing the most active authors, and a series of smaller networks that are both independent from the main network and from one another.

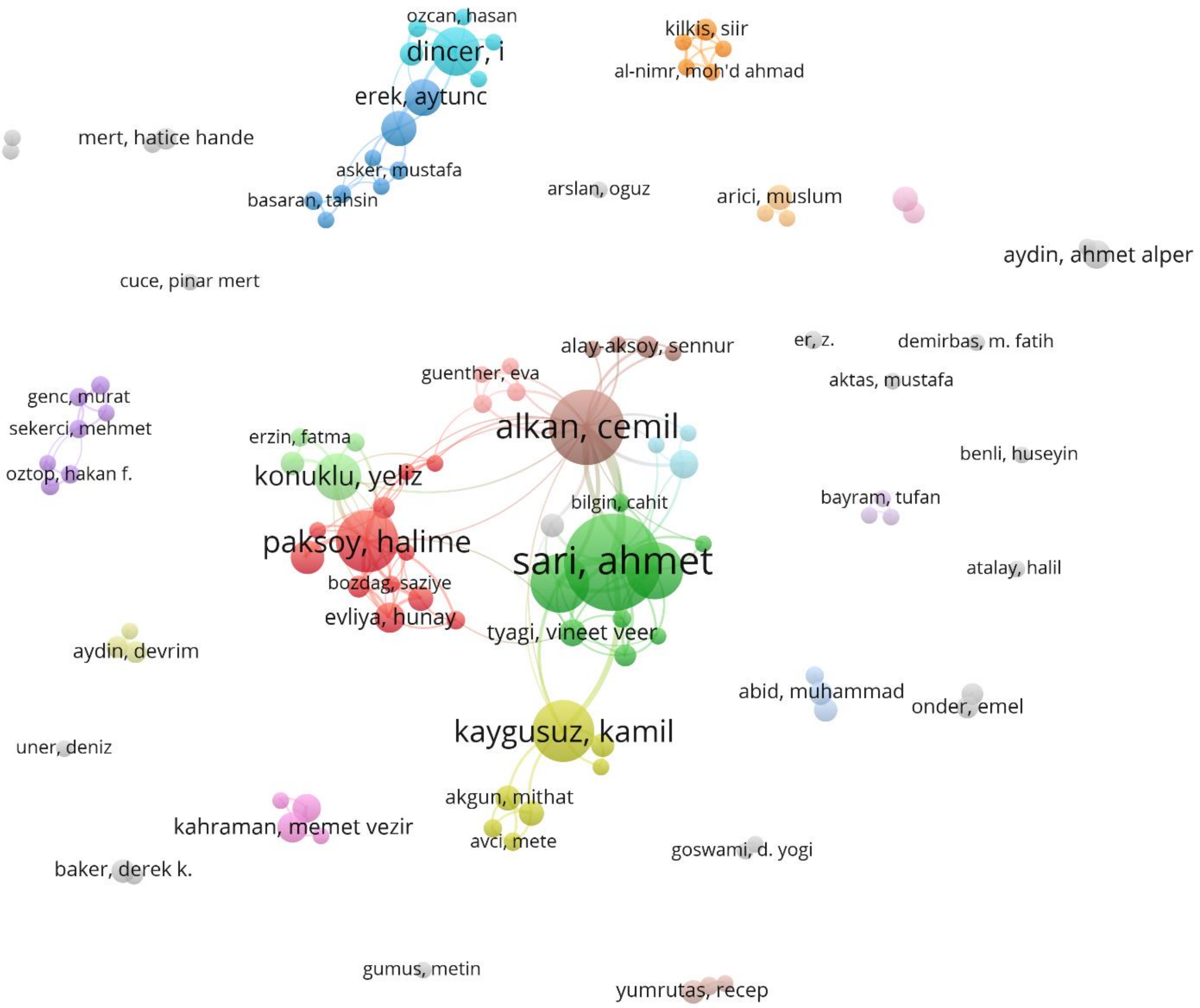

Figure 3: Coauthorship network (coauthors with a minimum of three publications, 113 nodes out of 768)

The number of publications or citations does not necessarily correlate with the total link strength of a node in the network. Here is the table for number of co-authored publications, citations received, and total link strength of the top 25 co-authors.

Author	Documents	Citations	Total Link Strength
Sari, Ahmet	99	6718	164

Author	Documents	Citations	Total Link Strength
Alkan, Cemil	58	2947	121
Bicer, Alper	34	1491	80
Paksoy, Halime	40	1256	73
Karaipekli, Ali	36	3938	69
Kaygusuz, Kamil	40	1499	44
Konuklu, Yeliz	24	541	37
Evliya, Hunay	10	481	30
Dincer, Ibrahim	25	578	24
Ezan, Mehmet Akif	13	174	22
Turgut, Bekir	7	137	22
Al-Sulaiman, Fahad A.	5	104	19
Tyagi, Vineet Veer	8	369	19
Doguscu, Derya Kahraman	9	176	18
Erek, Aytunc	15	494	18
Mazman, Muhsin	5	349	18
Akgun, Mithat	7	321	17
Aydin, Orhan	7	321	17
Cabeza, Luisa F.	5	265	16
Sahan, Nurten	12	299	16
Uzun, Orhan	6	680	16
Basturk, Emre	9	25	14
Kahraman, Memet Vezir	10	25	14
Bozdag, Saziye	3	26	13
Hekimoglu, Gokhan	4	16	13

Table 1: Co-authorship network

As for the institutional collaboration, the affiliations of the most scholarly productive researchers are in the network. However, it is also possible to track their international collaborations in the network. Figure 4 below shows 59 organizations out of 236. In addition to Ontario Technical University and King Fahd University of Petroleum Minerals, Shri Mata Vaishno Devi University, University of Nottingham, Technical University of Munich, Universitat de Lleida, and University of Barcelona are among the important international nodes for Turkish Scholars in CSP/STE Research.

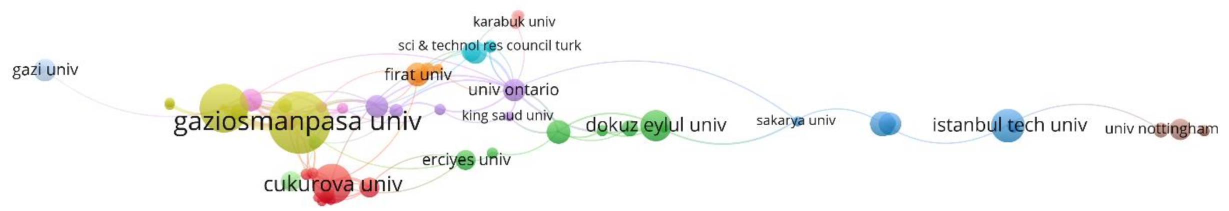

Figure 4: Organization network (organisations with a minimum of three publications, 59 nodes out of 236)

The collaboration at the country level can be seen in the Figure 5. Turkish researchers are collaborating with researchers from 39 different countries. Canada, Saudi Arabia, Germany, and Spain are among the most frequently collaborated countries where researchers are affiliated with.

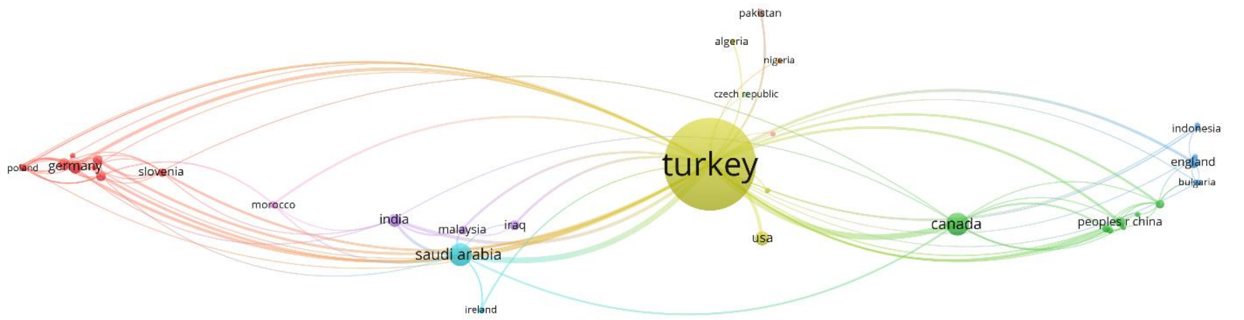

Figure 5: Collaboration at the country level (a minimum of one publication, 40 countries in total)

The funding for these research comes from different sources as shown in Figure 6. The Science and Research Council of Turkey (TUBITAK) is the leading national funding source. Scientific Research Projects (BAP) are also important; however, as they are provided by the respective universities of the researchers, they are listed here with the university names. There is also international funding for some of the research conducted. European Union (6), Spanish Government (5), COST (4), Federal Ministry of Education Research – Germany (3), National Science Foundation – USA (3), Department of Energy – USA (3) and Natural Sciences and Engineering Research Council – Canada (3) are the other international funders.

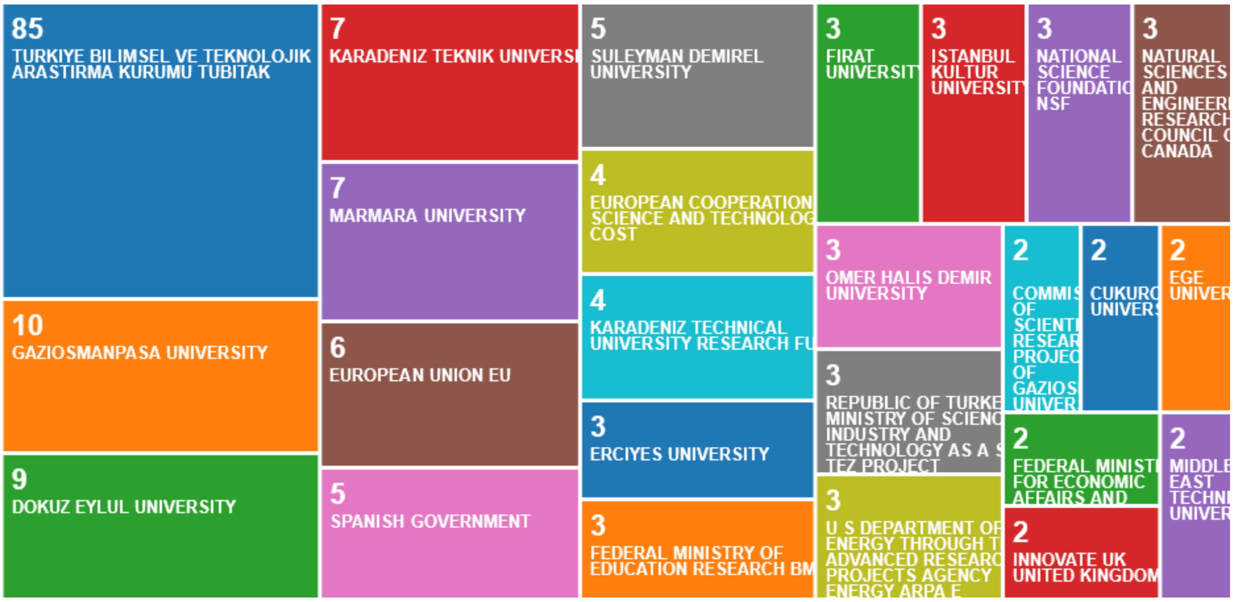

Figure 6: Top 25 funding sources

Figure 7 shows the research areas identified in our article search of CSP. It is apparently seen that the CSP research is quite interdisciplinary. Energy, chemistry, physics, chemical engineering, sustainability science, mechanical engineering, and environmental sciences are to name a few of these areas.

Figure 7: Research Areas related to CSP

A keyword map of CSP research (Figure 8) can also provide an insight to the interdisciplinary of the research. The co-occurrence network map provided below. There are eight clusters (each colour represents a cluster). As it is evident from the map, the keywords have been intertwined with each other. These keywords or phrases come from the titles, abstracts, and keywords of the 483 articles in our dataset.

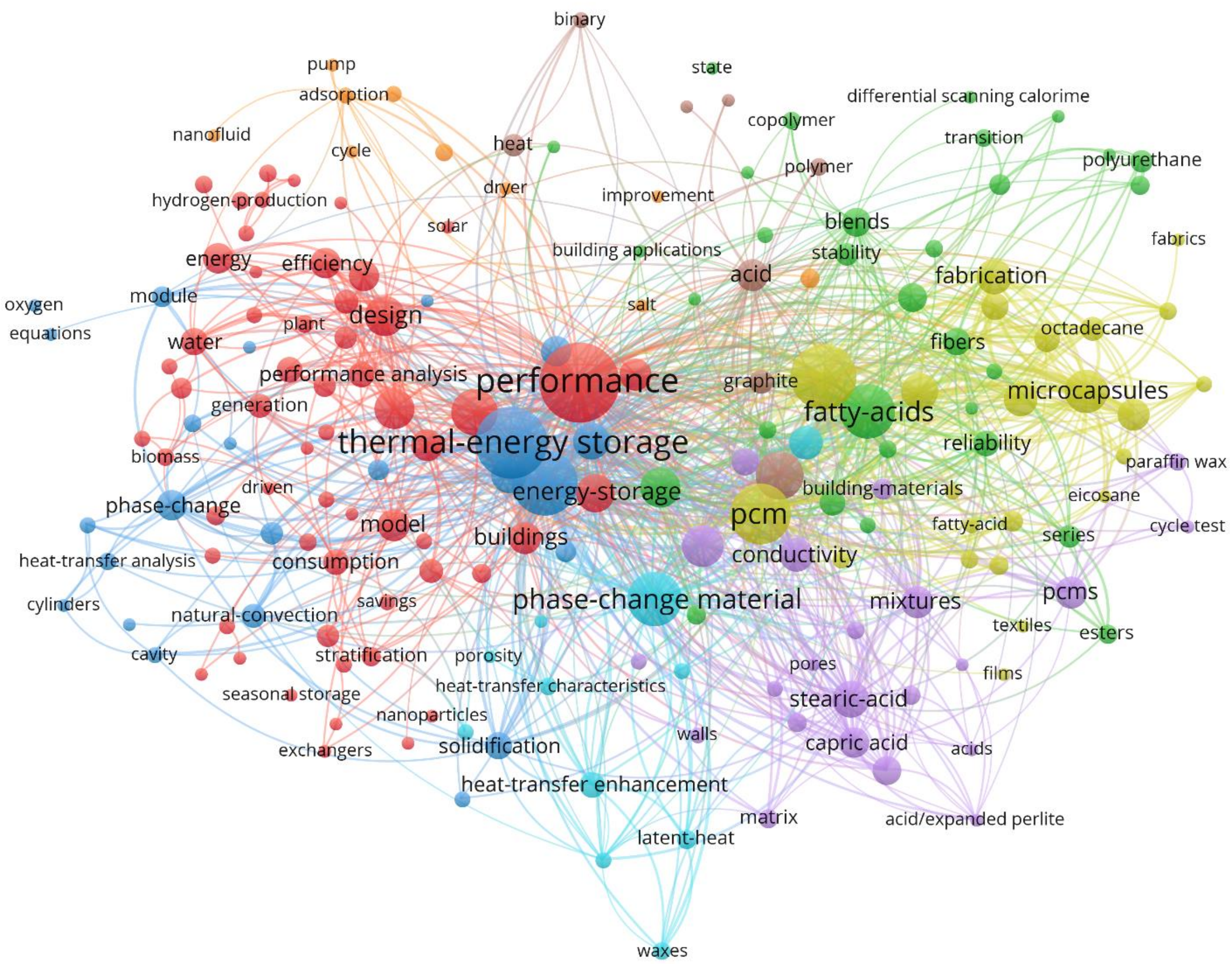

Figure 8: Keyword map (minimum three times, 187 keywords out of 812)

1.3.2 Overview of the context for industry

1.3.2.1 Energy policies and the place of STE in the landscape

The energy mix in Turkey represents a total of 90.4GW of installed capacity (as of July 2019[6]), of which 43.9GW of renewables[7]:

- 28.4GW of hydro.
- 7.2GW of wind.
- 5.4GW of solar.
- 1.4GW of geothermal.
- 1.5GW of others.

[6] *Source: Turkish Ministry of Foreign Affairs [online]*

[7] *Source: Turkish Ministry of Energy and Natural Resources [online]*

Despite this share of renewables in its mix, the energy dependency of the country is still above 70% and is a point of concern to build the existing and future Turkish energy strategy.

Turkey has always looked at a variety of solutions for its energy mix and intends to keep going this way, making a priority of a diversified energy mixed. Hydro is the major renewable energy source, representing almost 50% of the total renewable energy installed capacity. Turkey has also a high potential for geothermal which will be further explored in the upcoming years, particularly as renewable heating and cooling is a serious matter of concern in the country. However, Turkey has also planned to almost double its resources in PV and wind by 2023 to strentgthen the share of renewables in the energy production and final consumption.

More precisely, Turkey has a series of targets to meet by 2027:

Type	Target	Deadline
Increase the level of renewable energy in total energy consumption (including hydro)	+30%	2023
GW of installed capacity	110GW	2023
PV capacity	13GW	2023
Wind capacity	14GW	2023
Geothermal capacity	3GW	2023
Share of RE and domestic sources in electricity generation	2/3	2023
Solar capacity	+10GW	2027
Wind capacity	+10GW	2027

Table 2: Renewable energy targets in Turkey

To reach these targets, an increase of the share of renewables in the system will have to be tendered. The current bidding system for renewables relies on a zone system (YEKA tenders). Each zone is delimited by the Ministry of Energy and Natural Resources (MENR) and is allocated a certain amount of additional capacity while incentivising local manufacturing of renewable generation assets. This system was implemented by a Regulation on Renewable Energy Resource Zones (YEKA) on October 9, 2016 and aims to[8]:

- Commission renewable energy resources much more efficiently and effectively through identification of renewable energy zones on the public, treasury, or private-owned territories.
- Realize the renewable energy investments much more rapidly.
- Manufacture renewable energy equipment in Turkey.
- Use locally manufactured equipment/components.
- Contribute to research and development activities through technology transfer.

The Power Purchase Agreement (PPA) in YEKA tenders goes beyond ten years, which is in Turkey the Feed-in-Tariff (FiT) period determined by MENR. Until 2020, PPAs for a 1GW solar plant and a 1GW wind farm were fixed at 15 years. The usual bidding system is organised as a reverse auction, which means that the lower price is the one prevailing,

[8] *Source: Guide to Investing in Turkish Renewable Energy Sector, Investment Office, 2019*

and tenders are technology neutral. So far, even though CSP has not been explicitly excluded from the tendering processes, it has nevertheless no chance to win a bid. Indeed, when only based on LCOEs, CSP has no chance compared to PV, as acknowledged by policymakers themselves. However, a new support mechanism is planned for the end of 2020, with unknown specifications at the moment of writing this report.

Two types of mechanisms can currently be applied in YEKA:

- An "Allocation on the Condition of Local Manufacturing": this mechanism defines in the Terms of Reference the locally manufactured equipment and other local components to be used in the zone by the winner of the tender. The latter must also settle its equipment factory on the Turkish territory and establish a Research and Development Centre.
- An "Allocation on the Condition of Using Locally-Manufactured Equipment": this system implies the use of components and equipments which have been locally manufactured by Turkish factories and which are composed of a certain ratio of local contents (defined in the Terms of Reference) and compatible with the national or international standards.

Even though the possibility of CSP use is not rejected in Turkey, the current policy framework is however not encouraging its development nor private investors to get interested in it. No specification for dispatching renewable energy at night has been implemented so far and none is planned at the moment, which could be the trigger for private investors to support CSP deployment in the country.

1.3.2.2 Energy regulation in Turkey: towards new regulations

EMRA (Energy Market Regulatory Authority, "EPDK" in Turkish) is currently operating under two types of systems: the licensed and the unlicensed systems.

Licensed systems concern installations over 5MW installed capacity. Regarding wind and solar projects, tenderers need to apply for a pre-license and have on-site metering data of at least a full 1-year period that has been collected within the previous five years for the sites to be used for installation of power plants. For the licensed solar projects in particular, only half of the data must be collected on-site.

Capacities for wind and solar are announced in advance, for the year to come, by TEIAŞ. EMRA schedules then the application deadlines. The bidding process is a reversed auction based on the tariffs, determined by MENR for each resource, in Table 3. During its first ten years of operation, the infrastructure will be granted the reduced RES Support prices instead of the fixed tariff. This system makes it difficult for large STE plants to be built in Turkey, as stated by EMRA itself, given the auction system which regulates it. Indeed, STE and PV fall under the same "solar" FiT category. As Table 3 shows, the current support mechanism allocates them the same $13.3 cents without distinction between the two technologies. For instance, Greenway had a project to build a commercial STE plant in Konya area. However, as reported by its former founder, the idea had to be forsaken due to lack of financing support, which could not make the project eligible under the tendering terms at that time. In addition to this issue, this shows that there are structural problems for energy investors to adapt to the existing procedures. It is thus impossible for innovative entrepreneurs to adopt these procedures alone. Private investors are, after MENR, the main influencers of the Turkish energy system landscape.

SCHEDULE I (Provision of the law dated 29/12/2010 and numbered 6094)	
Type of Production Facility Based on Renewable Energy Resources	Feed-in-tariff Prices Applicable (US Dollar cent/kWh)
a. Hydroelectric production facility	7.3
b. Wind power-based production facility	7.3
c. Geothermal power-based production facility	10.5
d. Biomass-based production facility (including landfill gas)	13.3
e. Solar power based production facility	13.3

Table 3: Applied FiT prices until December 2020

The existence of Organised Industrial Zones (OIZ) has also implications in the possible location of STE plants, particularly when considering the production of process heat. Only very specific zones can welcome STE in Turkey, i.e. mainly the Anatolia area. Matching industries and renewable energy resource zones can prove challenging when it comes to STE and its specific DNI needs. As states the new Regulation for OIZ[9]" the establishment of the energy generation facilities using solar and wind power, other than the ones established for the OIZs' and their participants' needs, is not permitted."[10] "The ones established for the OIZ's and their participants' needs" is the key part here. These particularities are defined in the Article 65 of the new law: OIZs have the right to establish and operate electricity generation facilities, primarily for their own need, within the OIZ area and without the condition of establishing a separate company, provided that they get permission from the Ministry. Unlicensed power plants (up to 5MW) are therefore allowed. With the upcoming new hybridisation regulation[11], localised off-grid solutions using CST / STE technologies for energy needs of the industry will also be supported.

At the moment, no connection capacity for licensed solar project is foreseen, as TEIAŞ has not announced any solar energy capacity for licensed generation since 2013. It is therefore not possible for EMRA to receive any license or pre-license application for solar energy until a formal call by the TSO has been made.

Contrary to licensed systems, unlicensed systems are not regulated by a yearly schedule: applications can thus run all around the year. Installations generating up to 5MW do not need a license but the connection point must be the same as the one of the consumption facility. Once built, the installation must be evaluated by the operator for its suitability to be confirmed within one year following the signing of the connection agreement[12].

[9] *OIZ Law, Resmî Gazete [online] (in Turkish)*

[10] *Souirce: Çakmak, "Turkish Energy and Infrastructure", Newsletter, Spring 2019 [online]*

[11] *See below for further description*

[12] *Source: Guide to Investing in Turkish Renewable Energy Sector, Investment Office, 2019*

Rooftop and façade installations follow a different procedure and can have a 10kW installed power capacity. The power purchase price is set for the first ten years.

Regarding CSP, there is one example of unlicensed project in Mersin (South-East Turkey). A 5MW CSP tower plant has been built by Greenway and is operating since 2013. This has been a premiere in Turkey and remains today the only example of operating STE installation in Turkey. However, the industry developers reported difficulties to have the plant evaluated by the operator, as no one had the relevant knowledge to properly carry out the evaluation, provoking further delay for the full operation of the Mersin installation.

In addition to foreseen changes in the support mechanisms at the end of 2020, EMRA is working in parallel on two new regulations. The first one, a **hybridisation regulation**, should be enforced on 1st of July 2020. There is already an open door in the existing legislation, with the article 46 64 of the Energy Market Law stating that a plant can use more than one energy source to be powered. The only limit is the available transfer capacity, which is announced by TEIAŞ every month. One of the aspects of the hybridisation regulation concerns combined solar integrated power plants. Namely, CST components could be added to a conventional thermal generation plant (i.e., coal or natural gas). This addition to an already licensed plant means that no further licensing would be needed for building the CSP infrastructure in the case of a hybrid system of old plants. However, the hybrid version of the plant cannot have a capacity higher than the one from the plant had before retrofitting. New plants presenting a hybrid model can also apply for license. This could be a key step for the STE sector to enter the Turkish energy market.

The second regulation in preparation is a **storage regulation**. EMRA wants to manage the flexible deployment of energy with the solution of demand-side participation. However, the complexity of the storage issue, in particular regarding the responsible stakeholder for it (i.e., TEIAŞ or the investors) implies that this regulation won't be enforced before the end of the year. This regulation will also clarify if the allocation of thermal storage without a solar field to a plant would be possible and under which conditions. This remains at the moment hypothetical and is to be further studied by EMRA's working group.

1.3.2.3 Energy transmission system in Turkey: the role of TEIAŞ

TEIAŞ, the Turkish TSO, has to answer the increasing demand of energy production while reaching the national objectives in terms of renewable energy integration to the system. Even though this level of integration is not yet significant enough to have any impact on its stability, the targets for wind and PV until 2027 might be a game changer. Taking these elements into account, TEIAŞ foresees a **need for storage of approximately 4000MW by 2025**. It has therefore launched, together with MENR, a study on pumped storage and batteries. Hydro is one of Turkey's geographical assets. The feasibility study defined places to build pumped storage, including coupled with standard hydro installations, as building new pumped hydro is very expensive. The study focused on the feasibility and the existing potential of the pump-storage hydroelectric central systems. Five hydroelectric centrals were identified as possible to renovate. The first project will be Gokcekaya HES. In Turkey, large scale hydroelectric power plants are located in regions where pump systems can be integrated with renewable energy power systems. Regarding the battery study, it revealed that the capacity offered by this technology is too low for transmission purposes and might be more appropriate for distribution operators. TEIAŞ is aware that, to avoid curtailment of renewable production, investing in advance in storage is key. Investment programmes have not been published yet but pumped hydro might be included in them.

However, following the national strategy implemented by MENR, TEIAŞ acknowledges the **need for a mix of solutions in terms of storage**. The combination of PV and STE, either on the same site or on different locations, appears as a promising one for the operator. Thermal storage is, both qualitatively and quantitatively, a solution seen as relevant, even more when compared to batteries. The presence of a rotating machine is the most appealing for a transmission system operator since it represents a real advantage in terms of system stability. Yet, without a clear decision from the Ministry of Energy and Natural Resources to clearly incentivise STE, investors will never support the integration of STE in the Turkish electricity market. To that extent, TEIAŞ is very interested in the Moroccan case, particularly regarding the clear renewable strategy implemented by the government. Several members are to participate in a workshop in Morocco in March to observe and gather information on renewables and their integration to the system.

In addition to the storage needed for further renewable integration, TEIAŞ is looking for increasing its **interconnection capacities**. The Turkish system is already interconnected with ENTSO-E through three points: one of 400kV with Greece and two of 400kV with Bulgaria. Studies are ongoing to see how these capacities coud be increased of at least two additional lines of 400kV each, one on each border. These interconnections are seen as decisive factors. They would not only impact the development of renewables and of storage but also reinforce Turkey's position as a bridge between Europe and Asia.

1.3.2.4 Financing energy projects: the example of Garanti BBVA

Garanti BBVA is the only bank in Turkey to directly invest in renewable energy projects. It focuses on the **electricity generation** and contributes to finance the **production sites**. As an integrated financial services group, Garanti BBVA has a 30% share in wind projects. Since 2015, it started significantly financing solar projects as well. As of 31 December 2019, Garanti BBVA has allocated all its project finance loans for greenfield power plants to renewable energy projects[13]:

- $2.53 billion to wind power projects.
- $2.42 billion to hydropower projects.
- $263 million to geothermal projects.
- $237 million to solar energy projects.
- $22 million to biomass energy projects.

The uncertainty around the continuation of the support mechanism and the form it would take is putting pressure on the financing system. The loaners are calling for benchmark prices to secure the continuation of financing. The current FiT which grants a maximum of $13.3 cents/kWh for solar projects for the next 10 years was an easy marker for modelling risk and finance plans. However, it is not clear yet if the new support mechanism will be labelled in dollars, Turkish lira or euros, which makes the entire question of the price blurry.

[13] *Source: Garanti BBVA, Integrated Annual Report 2019, 2019 [online]*

Apart from the FiT, banks are calling for:

- An **increase of the long-term financing**. They have been aligning on the 10-year FiT, but for instance 12 years would already be a stronger signal for investors.
- This is directly linked to the need of **a sustainable cashflow**, such as a PPA. The limit is that PPAs in Turkey are not long-term (1 – 2 years) while a twelve-year guarantee would have a bigger impact on the financing side.
- A **need for guarantees**: a project should not have a merchant risk higher than 20% of the total of the loan once the support period is over. This means that if the government decides to go for a 5-year feed-in-tariff support mechanism, then the project would have to already limit its merchant risk to 20% of the total loan already after 5 years.

To be sustainably financed, innovative technologies should provide higher capacity factors. It should be approved by independent technical advisers. They would review the technology, the investment costs, the time it would take for the investment to be finalised and all the existing risk factors. Sponsors must also be seen as reliable.

Storage is considered an asset for the energy system, and thus a factor of market stability. As Garanti BBVA has never financed any kind of storage project, STE + thermal energy storage (TES) is seen as a new technology for them. They thus need a full risk-assessment and experts to turn to, to better grasp the full potential of the technology on the market and evaluate potential return on investment. For bankers to be able to value the flexibility provided by TES, there could be, for instance, a clause system in the project financing terms regarding the sales of electricity to the market. To observe the development of financed STE projects, the government should make a study to provide some **benchmark levels for the sales and fixed price** that it can offer (PPA, FiT, …). This would give banks a sustainable and reliable modelling.

1.3.2.5 A big industry potential not yet fully-fledged

The STE sector is currently limited from an industrial point of view in Turkey, mostly due to the combination of lack of information and awareness about the technology and the **absence of mechanisms allowing a fair return on investment**. As a result, no private investor has been involved in the financing of such projects. Except one company, Greenway CSP, which was a precursor in building a 5MW tower in Mersin in 2013. According to its founder, the aim of Greenway CSP was to lower the LCOE for STE, focusing on the heliostats as well as on the different cycle pssibilities. For instance, Greenway wanted to focus on Brayton cycles which showed a maximum of 27% of efficiency: they found out that the use of small unit plants combining Rankine and Brayton cycles could increase the efficiency up to 60%.

This young industrial potential was stopped as administrative procedures delayed the process and sponsors were not easy to find. Greenway CSP has thereby ceased activities. However, the commercial interest in STE did not fade away. Turkish research in STE, in particular linked to METU-GÜNAM activities, is very active, as shown in the R&I part of this report. The participation of some companies such as Tekfen in CSP ERANET calls, whose aim is to “bridg[e] the gap between research and commercial deployment in the

Concentrated Solar Power (CSP) technology"[14], is also an indicator of the **will of Turkish companies to diversify their involvement in energy technologies and to strengthen their presence on the energy market**. Finally, the recent launch of the $ODAK_{2023}$ programme, in which ESTELA took part, allowed ESTELA to paint a broad overview of the commercial potential of Turkey regarding the development of STE at a national level. The presence of several actors from a broad range of industry sectors showed the interest arising for commercial opportunities and positive initial conditions for vitalising the STE industry in Turkey. Companies working on solar trackers, heat recovery systems, thermal management systems, heat exchangers or storage tanks, *i.a.*, were presenting their current capacities to contribute to the launch of STE in Turkey.

Barriers to the commercial development of STE in Turkey therefore does not come from a lack of industrial interest. The lack of investors represents the main barrier faced by industries. The use of LCOE as main investment criteria for installing new energy capacity in Turkey is strongly deplored by the different industrial stakeholders. According to some actors from the solar sector, the figures which are put forward by the PV sector are not in favour of STE. Yet, **Turkish companies could contribute more in terms of capabilities to CSP technology than to PV**, which is almost exclusively relying on China's know-how and price competitiveness.

More than insisting on the competitive aspects, most of the companies and industrial stakeholders call for the **implementation of smaller projects and more cooperation and complementarity between technologies**. To combine STE with low-cost technologies like PV and to design precise and adapted criteria for construction and generation remuneration would help kick-start the deployment of STE. Former and current industry stakeholders underline that bringing technologies and manufacturers together to design small compact units would represent a turning point. Instead of half a billion-dollar for a 100MW project, it would be four times cheaper to build five small units of 20MW each for an estimate of about 20-30 million dollars investment. In addition, the versatility of STE, including thermal desalination, commercial activities, local steam production, multiplies the possibilities of use of the technology. These layers are most likely to be commercialised in the short run, which would in return ease the diffusion of the technology. Smaller projects would be a smart step towards bigger projects and would require less land to be used, facilitating an increasing presence of STE technologies in Turkey.

For industry stakeholders, know-how and procurement opportunities are a priority for them to commercially develop the sector. The local aspect comes second. They want to meet the market LCOE level, and not to always need the help of the government or the entities for loans or many regulations. Namely, virtual PPA opportunities create great investment opportunities – or at least has it done so in the US. To lower the price per kWh remains a priority, which can be achieved through the multiplication of small projects.

[14] *Source: CSP ERANET website [online] [consulted on 23/03/2020]*

1.4 Key findings

1.4.1 R&I

- There is robust research infrastructure & qualified cutting-edge research in Turkey for technology development and domestic production of the equipment.
- Commercialization and industrialization of the research in one of the most important aspects of the realization of the R&I activities.
- For companies, Solar Heat for Industrial Processes (SHIP) is promising, and variation of implications for CSP/STE Technologies including hybrid solutions and power plants are promising areas for development and diffusion of CSP / STE Technologies.
- Integration of both industry and university to EU Research Networks is seen as a critical gateway for local integration to global value chains and diffusion of technology.
- There is an established Political and Regulatory framework for Renewable Energy in Turkey. However, the Support Mechanisms specific to CSP /STE technologies and implementation should be designed.
- For the future of the technology, Energy Mix, including Renewable Energy and SHIP implications would be the main focus.
- The CSP / STE in Turkey started to take off in the early 2000s, and Turkish researchers are publishing more CSP related research. In the last two decades, it reached to more 50 publications per year.
- More than half of (63%) of CSP / STE related publications addressed Turkey is affiliated to 6 most productive scholars. Each of these scholars has more than 40 papers in the field. These researchers are affiliated to the Engineering Faculty and Arts& Sciences Faculty, and they have secure international and national networks that link them the nodes of most productive networks in the Country.
- The CSP / STE Researchers are tightly integrated to European networks via their collaboration with universities and research organizations in European Countries (such as the University of Nottingham, Technical University of Munich, Universitat de Lleida, and the University of Barcelona) and funding resources of their published research (such as European Union, Spanish Government, COST, Federal Ministry of Education Research – Germany).
- CSP research in Turkey is quite interdisciplinary. Our bibliometric analysis pointed out that Energy, chemistry, physics, chemical engineering, sustainability science, mechanical engineering, and environmental sciences are to name a few of the research areas that contribute CSP / STE Research. This interdisciplinary can be seen in the keyword map that encompasses various keywords that are studied by different disciplines.

1.4.2 Industry

The different actors involved in the energy sector, from the institutional side to the commercial one, showed no opposition to the deployment of STE in Turkey. Several signs opened the door to a deeper discussion on different STE application possibilities, even though some hurdles must be overcome for a sound and sustainable STE and mostly CST development to take place.

1.4.2.1 A three-pillar foundation for an STE business case

The most important element which must be accounted for when approaching stakeholders can be summed up by three key concepts.

First, the **capitalisation on existing technological and research capacities**. The current state of play regarding research and industry in Turkey – but not only – is of prime interest when looking for potential solutions to use STE. In Turkey, research on potential STE uses and improvements is already quite active, in particular through the work of METU-GÜNAM. Turkish companies or branches of international companies implemented in Turkey are already developing specific knowledge in fields such as cycle analysis, turbines, compressors, working fluid selection, receivers, heliostats and energy storage solutions.

Existing companies with a declared interest / experience in STE are the following ones:

	Name of the company	Area of expertise
1	Ekodenge	CST usage in industrial zones: to determine the environmental impact of the life cycle processes of products
2	Pars Makina	Solar tracking (normally used for PV); heat recovery; cycle analysis, turbine, compressor, working fluid selection, receiver.
3	Ileri Arge	Semiconductor. Experience in PV.
4	GKE energy	EPC provider for commercial and utility-scale PV, CPV, and CSP solar projects
5	OKYAY ENERJİ	Thermal system (Atomic Layer Deposition)
6	Sisecam	Flat glass production. Experience in cogeneration for industrial steam.
7	SOCAR	Oil and natural gas company. Storage. Solar pyrolysis, solar heating of industrial streams, catalytic reactions via concentrated solar power
8	Temiz Yaratıcı Teknolojiler (TYT)	Works on Hybrid Geothermal And Concentrated Solar System. EPC, O&M.
9	Tekfen Engineering	Storage, heliostats (as currently involved in a CSP Eranet call)

Table 4: First list of potential companies to actively contribute to the deployment of STE[15]

Each of these companies are already well established in Turkey and are willing to extend their current knowledge to different use of STE, from industry heat to electricity generation and storage systems. Keeping in mind the specificities of each of them and their needs in terms of R&I is of prime importance. This means not only including them in

[15] *Based on the list of interested stakeholders of the SolarTwins kick-off workshop*

project planning but also favouring the local economy by involving national players in knowledge transfer.

This is the second pillar of a good business case for Turkey: the **localisation of resources**. To push the government to give more support to the deployment of STE technologies, it is essential to give national actors a key role to play. The economic impact of such a configuration would be the best argument for more support to the technology. The example of Spain is quite striking in this regard: if at the beginning the technology was 80% German and 20% Spanish, the proportion reversed after 10 years, broadly profiting the Spanish economy and industry. **The concept of knowledge transfer** must be taken seriously when preparing a project in Turkey. MENR has made it a priority to design energy policies targeting the development of national technology development capabilities. This implies the involvement of existing companies who showed willingness to deploy their offer in this sector and could pave the way for the creation of new industries and new dynamics in the energy sector to benefit the Turkish economy. On top of that, this would allow Turkey to develop a particular knowledge in the sector which could benefit other neighbour countries of the region while improving its energy security.

Last but not least, for any project to be considered, it must demonstrate that it helps **meet the system requirements**. This is not only defined by TEIAŞ but also, to some extent, by the government. If the TSO defines the energy needs to ensure the stability of the system, it is the government which designs the types of sources that should be added to the system. When considering an STE project, what matters is to demonstrate the true value of STE to the stability of the system. With the increasing penetration of variable renewable energies, such as the additional PV and Wind capacities foreseen by 2027, the need for a sustainable base load will be more pressing (especially if it is intended to reduce fuel imports).

The combination of these three elements has been repeatedly underlined by the different stakeholders who helped shape potential STE solutions matching Turkey's energy needs. This combination is the first and main outcome to be considered when approaching Turkey.

1.4.2.2 A potential dynamic industry sector exists

Greenway CSP started paving the way of STE in Turkey, building the first (and only) operating CSP tower in the country. Its return on experience has provided important inputs for future companies but also to better understand the general frame in which energy projects are taking place in Turkey. Despite existing barriers, the main piece of advice from Greenway – which was confirmed by institutional actors – is to **attract industries to contribute to small projects**. The more projects are developed, the more companies get involved and the more technological knowledge is strengthened. Greenway started with a 5MW tower project. Even though no further projects could be unfolded afterwards due to sponsoring problems, the company gained valuable experience. It acquired a first grasp of the technical and administrative hurdles, which would make future experiences smoother.

Even though, historically, only one company has really been active in the STE sector in the last decade, a **promising industrial pool** does exist in Turkey's industrial landscape. During the event held by METU in February 2020, thirteen different companies registered and showed interest in further deployment of STE in Turkey, as direct actors or potential beneficiaries. Nine out of thirteen can be considered as potential direct actors in the deployment of STE and have been listed in Table 4. The variety of their fields of activities shows how Turkish industries could cover most of the value chain in the production of STE material, from heliostats to receivers, heat exchangers and storage. Some of them have experiences in other energy technologies, which can also be an advantage for the combination of technologies and more penetration of STE. For instance, SOCAR, being an important player in gas production, could lead the way to STE hybridisation. Others, such as Ileri Arge or GKE Energy, could make their PV experience benefit from STE thanks to storage opportunities, and thus support further their production capacity.

Finally, the other four companies which attended the event, if not directly relevant for material construction, appeared as potential off-takers of STE technologies. Indeed, sectors such as zoos, aquariums or logistic expressed interest in the use of solar applications to support their activities. Process heat, industrial steam and heat recovery are potential STE uses for Turkish companies. These industrial uses would not require a connection to the grid, which would make the construction of a unit easier – no license would be required. In that sense, the OIZ regulation is advantageous for any type of company settled in OIZ and which wants to establish a power plant (including the renewable energy technologies) to use for their own energy needs in industrial production.

There is thus a real potential for the development of Turkish STE actors. **Technical interest and potential demand from other industrial sectors** represent a strong foundation to develop further the technology in Turkey.

Three factors could possibly contribute to the dynamic of the CST sector at large in the near future: the need for storage, the need for heat and the upcoming regulation on hybridisation.

1.4.2.2.1 Future foreseen storage needs

The evolution of the energy landscape in Turkey has pushed the TSO and MENR to look into storage solutions so that system requirements are met. An estimate of 4000MW of storage, as expressed by TEIAŞ, would be needed by 2023 in order to ensure the stability of the system. Even though this storage issue is mostly considered under the scope of pump-hydro (see section 1.3.2.3 of this report), the use of STE and its thermal energy storage (TES) system is not *a priori* discarded by the system operator nor by any other authority.

This is a key argument for industrials to see a positive landscape to develop STE market in Turkey. With the upcoming hybridisation regulation, the combination of PV farms and STE with TES is also a solution to widen the perspective for the technology to unfold in the country.

1.4.2.2.2 Heat as a primary need in Turkey

However, the short-term potential for CST to unfold in Turkey at the moment relies mainly on industrial heat and heating and cooling. During meetings with representatives of the Ministry of Energy and Natural Resources, a significant emphasis has been put on the need for Turkey to develop more sustainable heating and cooling grids. As reported by

MENR, the South of Turkey would in particular require cooling. It happens to be also the part of the country with the best DNI (approximately 1,800kWh/m²/year), which makes it possible for CST to be explored. A possible combination with geothermal has also been mentioned by several representatives from MENR, as Turkey possesses very good geothermal resources and plans to deploy these applications in the upcoming years. This could be the opportunity for the CST technology to have small projects developing in the country, and thus show the performance of the applications.

The same could apply to industry heat. The multiplication of applications for process heat is looked at by the MENR. The new law for OIZ could foster the development of such applications and therefore contribute to proving the efficiency and relevance of the technology for a potential electrical use in the mid to longer term.

1.4.2.2.3 Upcoming regulation on hybridisation

The new regulation on hybridisation represents a real opportunity for CST industries to grow. It will facilitate the processes for investors and innovators. The reduction of administrative burden which the possibility of adding an additional source of power generation to an existing power plant without going through the licensing procedure.

As structural burdens have been identified as obstacles for industries to carry out STE projects, such as in the Greenway case, this new perspective sends a positive message towards industrial players.

1.4.2.3 The general context indirectly influences the industrial canvas

Besides encouraging signs for STE in Turkey, the different existing hurdles must be born in mind to offer solutions which match the needs and interests of the country at best.

1.4.2.3.1 Fostering investment

The macroeconomic instability resulting from the global Covid-19 pandemic unfolding at the time of writing this report is a serious challenge to the development of innovative industries. Indeed, the uncertainty regarding recovery plans and also the global impact on companies, projects and support mechanisms is still unknown. Many projects which were financed with support mechanisms running until 2020 in many countries (as is the case in Turkey), may experience delay in delivery.

In order not to jeopardise the development of renewables and to help companies maintain their heads out of the water, the International Energy Agency has come up with three potential solutions[16]:

- To extend the deadlines for commissioning projects beyond 2020.
- To include financing and incentives for renewable projects in upcoming stimulus packages.

[16] *Source: International Energy Agency, "The coronavirus pandemic could derail renewable energy's progress. Governments can help", 4 April 2020, IEA website [online]*

- To align short-term policy actions with new medium and long-term strategies to maintain the 2050 emission targets. This includes the development of electricity infrastructures and the funding of new technologies.

This could be the opportunity for CST to find the necessary investment ecosystem in Turkey, since a strong political signal would be sent to companies.

1.4.2.3.2 Support mechanisms

There is only one “solar” category under the current scheme, which is labelled “solar power-based production facility”. This means that **no difference is made between PV and STE**, which are both auctioned at $13.3 cents/kWh, regardless their different added values. When combined with the problem of investors, this results in a dead end for STE and unfair terms of competition. Indeed, the comparison between the two technologies is not based on equivalent features. If STE is bluntly more expensive than PV in terms of CAPEX, the services offered are however not the same: manageability, higher energy capacity… As long as these added values are not taken into account, STE will never be in position of competing with PV.

This is a vicious circle when added to the main challenge encountered for the deployment of STE as developed in the previous section. The lack of investment triggers no further development of projects, the lack of project development does not influence a drop in the costs, the high costs do not allow competing with PV, which does not attract investors. Hence, there is a need for the new support mechanism to take these limits into account.

However, the **status of this support mechanism after 2020 remains unknown** while we are writing this report. To turn it into an asset for STE, the Ministry of Energy and Natural Resources should take into account several elements:

- To separate different technologies in different auction pools. **STE and PV can no longer be considered under the same category**. The use of LCOE as main criteria for the attribution of tenders can never benefit STE under these circumstances. PV would always provide cheaper LCOEs and show lower initial investment. This means that attracting investors would remain a challenge for STE projects and significantly hurdle their deployment.
- To consider labelling tenders which **take into account the production of renewable electricity at night**. This would have two benefits. First, this would make it possible for STE to enter the competition, thanks to its storage capacity which allows the plants to dispatch energy even at night time. Second, this would contribute to more penetration of renewable energies in the Turkish energy mix: instead of a baseload made of coal or gas at night, solar energy could kick-in.
- To **auction solar energy production including storage**. This would give way to three solutions: PV+battery, STE, PV+STE and open a fair competition between the different possibilities. In addition to that, it would also strengthen the stability of the system, adding more storage possibilities which could relieve the system in times of tensions.
- To support generation of needed energy in industrial production from renewable energy technologies or hybrid systems rather than subsidising electricity used in industrial production.

The past mechanism has taken into consideration some technological innovation system actors and their competencies, which created advantages for other renewables. However, until the new support mechanism conditions are known, it remains as such a barrier to the development of STE plants or applications in Turkey.

1.4.2.3.3 Turkey's energy strategy

Energy policy is highly strategic for Turkey. Energy security is one of the key concepts of the Turkish energy plan for 2023, as stated by the Turkish government[17]. The development of domestic production, particularly through renewables such as Wind and PV, is therefore a priority for the country. The more penetration of these two sources in the energy mix, the less need for energy import. However, the more variable renewable energy sources are incorporated in the energy mix, the more flexibility of the grid is required. STE could therefore play a role here, through its manageable characteristics, provided that potential entrepreneurs are made aware of the possibilities of this technology.

Turkey is still relying heavily on coal and shows interest in attracting foreign investors to further develop national coal exploitation [18]. Coal is still one of the prominent sources of fuel that can decrease the import dependency in Turkey's energy production, since Turkey has coal resources (even though very low in efficiency). Due to the energy strategy of Local and National (Yerli and Milli) levels, coal is still an important fuel in Turkey. However, its existence can be seen as an opportunity for STE technologies: hybrid plants can be thought here as an option for heat, and also to plan potential future retrofitting of these plants. As hybridisation is getting more attention thanks to the new regulation, STE / CST technologies can find a breach there to impose themselves and contribute to increasing the efficiency of energy production from the type of coal which is mined in Turkey.

Turkey is also opening a four-unit nuclear power plant of a total capacity of 4800MWe in Akkuyu, province of Mersin, with the help of the Russian VVER technology. It should be commissioned by 2023[19]. In addition to this nuclear plant, a second one should also be commissioned by 2023 in Sinop province, in collaboration with Japan. The construction of a third one in the Thrace region was announced in 2018 and will be built with China[20]. This strategic choice might constitute an obstacle for the development of big STE projects in the country, due to the costs of construction and also the relatively long-life duration of nuclear power plants.

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[17] *Source: Presidency of the Republic of Turkey, Strategy and Budget Presidency, "Eleventh Development Plan (2019-2023)", July 2019*

[18] *Source: Turkish Ministry of Energy and National Resources, "Investors' Guide for Electricity Sector in Turkey", Second Edition, October 2019, MENR website [online]*

[19] *Source: Turkish Ministry of Energy and National Resources, MENR website [online]*

[20] *Reuters, "Turkey to build third nuclear plant in Thrace, cooperate with China", 8 August 2018, Reuters website [online]*

On the renewable side, Turkey is already well advanced in hydro, which represents almost a third of the total installed capacity[21]. Thus, priority will be given to investments in existing capacities, to refurbish them and see how to increase the country's storage capacity. Turkey also showed interest in exploring geothermal power, since it possesses good resources, as located on an active tectonic zone. Thanks to the current projects under development, the geothermal capacity should amount 2GW by the end of 2020.- Investments in renewables is expected to be promoted in the future, especially because of the increasing prices of natural gas and the current debate on self-sufficiency and energy security[22].

As a whole, even though the Turkish energy strategy is not at the moment investing in STE, the promotion of renewables in opposition to the use of natural gas, as well as potential hybridisations with coal power plants leave the door open for CST industries to develop their activities in the country.

1.4.3 Integrated findings

Following a close monitoring of the situation in Turkey from both the research and the industry sides, key integrated observations can already be seen as pillars for joint conclusions and recommendations.

1.4.3.1 Turkey is favourable to renewables, but further consistency in energy policy should be sought for

- Two important dimensions must be accounted for when designing a RES project: opportunities for domestic production (including national production of components), and the use of national resources (aka existing technological and academic knowledge). However, the domestic/local production is not yet at the desired levels in energy technologies: this leaves an open door for future RES development, in particular for STE, as academic research is already well advanced.
- There is a lack of interdisciplinary and transdisciplinary studies. The development of a sustainable energy policy could be favoured by a co-benefit strategy that should be implemented for decreasing carbon footprint and global climate crisis.
- YEKDEM is a correct policy initiative for renewables, but the regulation should be more flexible to allow further diversified penetration.
- There is a problem with a system which does not favour any technology: by choosing to try and develop all, problems are caused and can hinder the development of adapted renewable technologies.

[21] *Source: TEIAŞ, "Turkish Electricity Capacity Production Capacity, 5 Year projection (2018-2022)", May 2018*

[22] *Source: Turkish Ministry of Foreign Affaires [online]*

1.4.3.2 Contradictions in the market system do not favour sustainable investment

- Market formation is important in terms of liberal free markets: it influences the volume of investment in specific areas.
- In addition to financial crises, macroeconomic instability, and external factors such as a global pandemic, Turkey is also sending mixed signals to investors. By promoting investment at the same time in coal and in renewables, Turkey lacks systemic concepts in renewable investments. Renewables are treated as minor energy producing technologies as compared to coal for instance, which diverts potential investments and does not reassure investors.
- Subsequently, compact and shortened investment processes for investments in renewables also question the sustainability of investments after public incentives are ceased to exist.

1.4.3.3 However, the overall energy policy in Turkey is not opposing the development of renewable energies

- There is a bright future for all renewable technologies thanks to the YEKDEM system.
- The opportunities for hybridization and possibilities for incentives also participate in this opportunity window.
- Turkey experiences problems with the base load and is yearning for energy security. Renewable energies are local resources and offer minimum load problems. However, the balance of electricity supply is problematic, as well as productivity problems in renewables when mostly based on variable renewable energy sources.
- Hence the need to diversify the RES and turn towards dispatchable systems with storage.

1.4.3.4 The gap between research and industry should be closed

- Problems regarding commercialisation of research findings in universities have been observed: more interactions with the industry and demonstration studies are needed, to follow the needs of the industry to further develop
- Glass/Mirror production competencies are important for CSP, together with nano fluid competencies: this knowledge and research basis are already developed in Turkey and could give way to industrial know-how of the country.

1.4.3.5 A sound potential for the development of STE if necessary measures are implemented

- Storage technologies are very critical for the Turkish energy system. STE technologies should thus always be introduced with thermal energy storage applications.

- However, costs remain the main obstacle for the development of the technology, particularly when comparing to the decreasing cost of PV and the absence of specific STE incentives. As long as LCOEs remain the main comparator, STE will need specific support to emerge in electricity production.
- Hence, CST applications should be more industry-oriented at the beginning, because of cost advantages of other electricity-producing technologies. The sole concern should not be producing electricity. Demand by industries would attract investors and cut the shortage of demand for these technologies. The advantages regarding industrial heating, and cooling applications should thereby be put forward and call for proposal for industrial applications of STE.

1.5 Aligned conclusions and recommendations

All the conditions, both on the industry and the R&I sides, show already a strong coherence as a fertile basis for the CST sector to unfold in Turkey: there is no reason for it not to happen. All aspects that have been surveyed allow the following overarching comments and suggestions.

1. Turkey is favourable to renewables, but further consistency in energy policy should be sought for

In countries where a market for a given technology does not yet exist, the deployment of a new technology primarily depends on industry and STI policy decisions which are subsequently embedded in a specific regulatory framework and operational targets. The basis for such policy discussions is the political assessment of what lies in the national interest of the country:

- National economies have built their largest industrial corporations around clearly defined industrial programmes and priorities to serve the national interest. However, some countries can choose, on the contrary, to develop multiple energy policy alternatives, instead of a core industry focusing on a core resource. They will then be more of a "**test field" for export-oriented corporations, rather than providers of solutions to a national problem**. This may become a potential obstacle or a brake to the development of renewable technologies with a very high added value on the mid- or long-term.
- There is therefore **a problem with a system which does not favour any technology**: by choosing to try and develop all, problems are caused and can hinder the development of adapted renewable technologies.
- The trigger for **establishing a market** for a new technology is therefore **neither its technological performance nor its costs**. Technology performance and costs turn out to be triggers for the further development/higher efficiency, namely within an already existing market featuring a larger number of competing actors.

This is also the case for Turkey, which has assessed that **three conditions must be met** to receive substantial support:

- **opportunities for domestic industries** (such as national production of components) but also export opportunities.
- **use of national resources** (besides natural resources, existing technological and academic knowledge).
- **almost implicitly, meeting national needs** (such as the need to ensure system reliability and security of supply of the power system in the context of a strong demand increase).

Regarding the **local industries,** which would be engaged in a larger deployment of STE in Turkey, they do **not appear yet at the desired technology level**, compared to international competitors, **to establish alone an efficient national STE market**. This might also be linked to a **lack of interdisciplinary and transdisciplinary studies** demonstrating the national benefits and the sustainability of decreasing the carbon footprint. This would contribute to both the Turkish national economy and the global fight against climate change.

However, this leaves an **open door for future RES development**, in particular for STE. **Academic research** has best international reputation and references. **Industry platforms** also play a role, where joint ventures with other companies could be considered and result in balanced setups of industry consortia, some technology transfer, and other shared benefits.

1. Contradictions in the market system do not favour sustainable investment

In addition to the effects of financial crises, macroeconomic instability, and external factors such as a global pandemic, **Turkey is also sending mixed signals to investors** by promoting investment at the same time in coal and in renewables, in particular since its main goals are to reach security of supply, decrease foreign dependency by using domestic sources (including solar and coal at the same time) and develop its own technology (indigenisation).

Turkey lacks systemic concepts for renewable investments, even though following a structured marketisation in renewable energy.

Renewables are treated as a secondary energy producing technologies, as compared to coal for instance, which diverts potential investments and does not reassure investors. However, hydro has a special role and is one of the major sources of renewable energy in various policy documents.

Subsequently, compact and shortened investment processes for investments in renewables also question the sustainability of investments after public incentives ceased to exist.

2. However, the overall energy policy in Turkey keeps the door open to the development of renewable energies

Turkey experiences problems with base load and is yearning for energy security. **Renewable energies** are sometimes seen only as **local resources** with minimum impact on load problems.

Therefore, it appears that a **strong support to balancing the power system** cannot be based on variable renewable energy sources, but should be **complemented by sustainable storage solutions**, for which STE could play a decisive role.

The **YEKDEM** system represents a **good opportunity for all renewable technologies** in Turkey. Even though the policy initiative for renewables goes in the right decision, the **regulation should be even more flexible to allow further diversification** of various complementary technologies.

The **opportunities for hybridisation** and possible new incentives also provide **new business opportunity windows**.

Unsuspectedly, **STE can also play a role in tourism**, as this is already the case in some countries[23], which is a distinctive asset which is not shared by many renewable energy sources.

3. The gap between research and industry should be closed

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[23] *An example: In France, there is a touristic path in the South which shows all STE installations in the region, including the Four d'Odeillo.*

There is still a challenge to improve the commercialisation of research findings in universities: more interactions with the industry and demonstration studies are needed, to follow the needs of the industry, for it to further develop.

Glass/Mirror production are a key component for STE and premium know-how about it as well as about nanofluid is a strong asset: the knowledge and research basis are already well developed in Turkey and could pave the way to better use this industrial know-how in the country.

4. A sound potential for the development of STE if necessary measures are implemented

Storage was reported as a critical issue for the Turkish power system over the next decade. A deployment of STE (plants with storage) in Turkey would make sense along other thermal energy storage applications.

However, the argument of costs remains the main obstacle for the development of the technology, particularly when comparing to the decreasing cost of PV and the absence of specific STE incentives.

To overcome this while strengthening the planning of a higher penetration of renewables in the power system of sunny countries, a fair comparison between technologies is needed. Assuming a firm commitment to a real energy transition is made, the question of the cheapest renewable technology able to compensate the loss of PV production after sunset should be addressed. This would avoid putting more pressure on market prices for PV power generated during daytime which would further pull down their already very low value.

Solar thermal power plants are a valid answer: they capture solar radiation during the day, store it in their tanks to produce electricity on demand during the night, slightly overlapping with PV generation at sunset to improve the ramping of the "duck" curve.

Using batteries with variable renewable technologies may in the future add some value for specific system needs at transmission and distribution levels. However, it will only make sense if batteries inject all their capacity into the system when the wind stops, or at sunset. Otherwise, they would deliver power at much higher prices than the variable sources during their operation. This would therefore not be sustainable since it would contribute to a so-called "price channelling". This does not correspond to the real backup needs of electrical systems, namely the ability to replace variable sources when these are no longer available, in various timeframes.

Introducing such considerations in the planning of the Turkish system may need some time. Therefore, CST applications should, at the beginning, be more industry-oriented because of cost advantages of other electricity-producing technologies.

Producing electricity is not the sole perspective for STE in Turkey. The demand for industry heat by various local industries may first attract investors so that industrial heating, and heating and cooling applications, should thereby be considered in calls for proposals for industrial applications of STE. This could be the best channel to introduce STE in the country.

5. Create a common advocacy platform and think political

To maximise the impact of a global coherence between research and industry, both should gather in a common advocacy platform, in which they would work together.

By uniting **representatives from the R&I and industry sectors**, the platform would embody the sector in its full spectrum and thus favour the consistency of its message. It would also facilitate the discussion between the two pillars of the sector.

Such a common advocacy platform would **help structure and give more weight to bring research results to market**, by offering a bigger weight in the political negotiations regarding energy policies and, most important, with the Ministry, which is the most influential entity.

It would therefore make it easier for research entities to have an **impact on financial institutions** and unlock potential funds for the industry: **having small projects**, adapted to the industry needs, funded in a consistent and sustainable way would attract investors and thereby open the possibility to have larger commercial projects.

The **risk-sharing of spin-offs** – if supported by the government – would drag more funds into a sector which shows good dynamic, and which is solidly aware of what it can bring to a complex societal ecosystem.

The multiplication of opportunities for (small) STE and/or CST projects offers the chance to tackle the LCOE issue.

If, politically speaking, **the LCOEs** are the reference value for allocating funds and favouring technologies, it is of major importance for the CST sector to prove that this **cannot be the only criterion**. By showing the assets of STE in projects and by building a Turkish CST narrative through the advocacy platform, it should be possible t**o build a strong case for reference criteria** which **go beyond LCOEs** and encompass **more complex and essential concepts**, such as flexibility for instance.

To call for a **strong and reshaped support mechanism**, not to a priori discard STE, is thus a key political mission for the stakeholder platform. **Political certainties must be acquired**, in order to thwart economic uncertainties and favour economic diversity, dynamism and competitiveness. STE can reinforce all of these aspects.

This platform could work along the following advocacy main lines:

A. What can cst deliver to the electricity sector?

The European solar thermal industry can provide **power on demand at utility scale**, without further delay, and at lower costs than renewable electricity stored in batteries or hydrogen. This is the timely **answer to the challenge of intermittency of PV and wind at sustainable costs**. This is possible via:

- **Complementing PV generation after sunset** which will contribute to achieve a more ambitious overall deployment of renewables with a higher impact on decarbonisation and prevent overinvestments in non-dispatchable technologies.
- **Constructing new innovative CSP plants with large thermal storage capacity** in Southern Europe and EU neighbouring countries with the best solar resources.
- **Revamping not only existing CSP plants**, but also fossil-fired installations with thermal storage facilities allowing a further use of existing generation and grid connection infrastructures, including fossil-fired plant sites.

- All this will **result in substantially reduced PV curtailments**, with an optimised use of natural resources across the continent, allowing shared benefits of bulk storage capacities and new strategic reserves amongst more Member States.

B. What can CST deliver for the decarbonisation of the industry sector?

The decarbonisation of the industrial sector will need more time and efforts than for the power system. Major contributions by renewable energy must be achieved through **high temperature process heat, sustainable fuels, and reducing agents**. This goes far beyond the potential that can be covered by biomass alone. This role and potential of CSP is particularly important for Southern Europe:

- **CSP can provide and store high temperature heat** (up to 900°C) at costs clearly below renewable fuels or electricity-based options.
- CSP can provide power and high temperature heat with a very high-capacity factor (7000h/year) to enable the decarbonisation of industrial processes.
- Due to these characteristics, it also allows an efficient operation of renewable fuel production facilities at constant load and at high-capacity factors – both essential to reduce the fuel costs.
- **It has the potential to decarbonise heat grids,** as it can provide and store heat more efficiently at suitable temperature levels (120°), compared to non-concentrating collectors, even in central European climate zones.

C. Why?

- Because **CSP is the cheapest renewable technology to avoid fossil energy backup**, making the energy transition easier in Southern European countries.
- To **reap the benefits of the complementarity** between PV and CSP especially, but also between wind and CSP, to make a larger penetration of renewables into the EU electricity sector possible.
- To reflect the currently non-considered value of storage in upcoming auctions for new renewable capacities and the full system costs.
- To foster European innovation and keep the European technological leadership in the field of CST, which is just at the beginning of its learning curve. Substantial cost reductions are expected if backed by strong R&I resources and a proven track record for industrial implementation.

D. When?

- CST can make a sustainable energy transition happen **right now, without waiting for "hoped-for-viability"** of other solutions. It will help match the upcoming bulk storage needs in the electricity and process heat sectors that could be used for harder-to-decarbonise industries.

- CST is a mature solar technology with a track record of over more than three decades that has already 'pulled' the development phase of a "solar industry" in Europe.

E. How?

- Include CSP and its characteristics into national regulatory framework conditions and tendering schemes for renewables electricity projects. The design of future auctions should include a market-based valuation of the flexibility added to the system by new capacity - under consideration of shifted or hidden costs of other generation sources ("cost channelling").
- **Adapt the current "least cost" system planning models** that was supportive to the deployment of fossil energy sources in the past but turns out to no longer be adequate for planning systems with a high share of renewables.
- **Provide access to comparable financial conditions** – as available to non-EU competitors on world markets.
- Finalise the features of currently prepared new financial support mechanisms (CEF, IF) to allow CST to fairly compete for eligibility.
- **Extend the concept of "sector coupling**" to be understood as optimising assets and resources of all renewables where there is a win in efficiency compared to "decarbonised gas" or biogas.
- Support **large scale CST demonstration** projects for high **temperature process heat** and **industrial decarbonisation** projects within a more ambitious European innovation ecosystem.
- **Improve funding to the R&I initiatives along the full CST value chain** to defend and consolidate the unique worldwide technology leadership of European companies.

F. What is the real cost/benefit ratio of a larger use of CST?

When confronting the two-fold objective of a "Green recovery", t**he use of LCOEs as only metric for investment decisions is no longer suitab**le for guiding investments since:

- CST technologies are just at the beginning of the learning curve with significant further cost reductions expected. The real ratio between incurred costs and benefits must go beyond LCOE and include a correct valuation of:
  - the added flexibility to the electricity systems via thermal storage.
  - the environmental impact for each sector (reduction of CO2 and GHG).
  - **the part of hidden or externalised costs** of single technology choices in the total system costs.
  - geopolitical effects on world markets and support to the European Union's Neighbourhood Instrument policies.

- societal and macroeconomic impacts on national economies due to new business cases for European companies with more sustainable jobs (local engineering, construction, and component supply chain as well as related services) that can not only substitute but also create jobs in the fossil energy sector.
- the recognised excellency of European research that brought to Europe a still undisputed technology and innovation leadership in CST.

1.6 Glossary

CSP	Concentrated Solar Power
DNI	Direct Normal Irradiation
EC	European Commission
EMRA	Energy Market Authority Regulator
ENTSO-E	European Network of Transmission System Operators
EU	European Union
FiT	Feed-in-Tariff
GWh	Giga Watt hour
H2020	Horizon 2020
IEA	International Energy Agency
IFIs	International Financial Institutions
IMF	The International Monetary fund
IRENA	The International Renewable Energy Agency
KfW	KfW Development Bank
kWh	Kilo Watt hour
kWp	Kilo Watt peak
LCOE	Levelised Cost of Electricity
MS	Member States (EU)
MW	Mega Watt
MW_e	Mega Watt of electricity
MW_{th}	Mega Watt of thermal energy
NECP	National Energy and Climate plan
OIZ	Organised Industrial Zones
PPA	Power Purchase Agreement
PV	Photovoltaic
R&D	Research and Development
RE-ZONE	Renewable Energy Source Zones
RES	Renewable Energy Sources
RES Certificate	Renewable Energy Source Certificates
SET-Plan	Strategic Energy Technology Plan
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TSO	Transmission System Operator
TWh	TeraWatt hour
YEKA	Renewable Energy Source Zone

1.7 Appendices

1.7.1 Reference

Turkey – R&I

Guide to Investing in Turkish Renewable Energy Sector, Investment Office, 2019 [online]

Çakmak, "Turkish Energy and Infrastructure", Newsletter, Spring 2019 [online]

Patton MQ. Qualitative Research & Evaluation Methods. 3rd Editio. California: Sage Publications; 2002.

Flyvbjerg B. Five Misunderstandings About Case-Study Research. Qual Inq 2006; 12:219–45. doi:10.1177/1077800405284363.

Aydınoglu, A. U. And Z. Taskin. Origins of Life Research: a Bibliometric Approach. Orig Life Evol Biosph (2018) 48:55–71 DOI 10.1007/s11084-017-9543-4

Turkey – Industry

Çakmak, "Turkish Energy and Infrastructure", Newsletter, Spring 2019 [online]

CSP ERANET website [online]

Deloitte, "National Renewable Energy Action Plan for Turkey", Ministry of Energy and National Resources, December 2014

Garanti BBVA, Integrated Annual Report 2019, 2019 [online]

International Energy Agency, "The coronavirus pandemic could derail renewable energy's progress. Governments can help", 4 April 2020, IEA website [online]

Power Technology, "Noor Ouarzazate Solar Complex, Power Technology website [online]

Presidency of the Republic of Turkey, Strategy and Budget Presidency, "Eleventh Development Plan (2019-2023)", July 2019

Presidency of the Republic of Turkey, Guide to Investing in Turkish Renewable Energy Sector, Investment Office, 2019 [online]

Resmî Gazete, OIZ Law, [online] (in Turkish)

Reuters, "Turkey to build third nuclear plant in Thrace, cooperate with China", 8 August 2018, Reuters website [online]

TEIAŞ, "Turkish Electricity Capacity Production Capacity, 5 Year projection (2018-2022)", May 2018

Turkish Ministry of Energy and Natural Resources, "The gross electricity consumption in Turkey in 2018 was 303,2 billion kWh", Turkish Ministry of Energy and Natural Resources website [online]

Turkish Ministry of Energy and Natural Resources, "Nuclear", Turkish Ministry of Energy and Natural Resources website [online]

Turkish Ministry of Foreign Affairs, "Turkey's Energy Profile and Strategy", Turkish Ministry of Foreign Affairs website [online]

1.7.2 Meeting guidelines

1.7.2.1 Ministry of Energy DG Energy Affairs

Introduction (10') Presentations

- visitors and the ESTELA association // thanks for availability
- check on practicalities (recording permission, notes, etc.)
- main purposes of HORIZON-STE, methodology (deepening of our understanding of the national perspective and how / consultation within the CSP sector and report by end of February where could Turkey could receive support from the CSP industry) , global targets, targets regarding Turkey

1. General perspectives of energy policy in Turkey (10')
   1.1. General targets and objectives
      - *Global energy policy drivers (economic, environmental, social, geopolitical)*
      - *Potential contingencies, bottlenecks?*
      - *Resulting priorities?*
      - *Latest forecasts / prospects resp. perceived opportunities for the Turkish economy?*
      - *Regional differentiation (get map)*

   1.2. Status of the raft Regulation on Energy Storage? *[e.g.: Is any specific technology favoured in terms of energy storage? ...]*

   1.3. Support mechanisms for renewable energies?
      - *current status?*
      - *Any foreseen adjustments of these mechanisms? What could trigger such changes?*
      - *What is the status of the (subsidised) long-term loans for renewable energy projects?*
      - *What is the status of the renewable energy cooperatives? Exclusively intended for the PV sector? ...]*

2. Particular aspects of interest for MENR regarding RES and CSP (20')
   2.1. Complementarity /convergence of Turkish energy policies with the EU's Green Deal plan? *[e.g.: Is the possibility of cooperation mechanisms known or used? What is the foreseen development of green energy in Turkey? Is the EU green ambition a motivator for Turkish energy policy? ...]*

   2.2. Planned implementation / procurement of solar generation? *[e.g.: Would the installation of CSP plants considered, as three regions present enough DNI? ...]*

   2.3. Hybridisation of conventional power plants? *[e.g.: As coal is a very important asset in Turkey, could it be hybridised with CSP? ...]*

1.7.2.2 Adviser to Energy Minister

Introduction (10')

- Presentations

- visitors and the ESTELA association // thanks for availability
- check on practicalities (recording permission, notes, etc.)
- main purposes of HORIZON-STE, methodology (deepening of our understanding of the national perspective and how / consultation within the CSP sector and report by end of February where could Turkey receive support from the CSP industry), global targets, targets regarding Turkey
- Can we expect a participation of MENR at the national event on 26/2?

1. General perspectives of energy policy in Turkey (10')

1.1. General targets and objectives

- *Global energy policy drivers (economic, environmental, social, geopolitical)*
- *Potential contingencies, bottlenecks?*
- *Resulting priorities?*
- *Latest forecasts / prospects resp. perceived opportunities for the Turkish economy?*
- *Regional differentiation (get map)*

1.2. Status of the raft Regulation on Energy Storage? [e.g.: *Is any specific technology favoured in terms of energy storage? …*]

1.3. Support mechanisms for renewable energies?

- *current status?*
- *Any foreseen adjustments of these mechanisms? What could trigger such changes?*
- *What is the status of the (subsidised) long-term loans for renewable energy projects?*
- *What is the status of the renewable energy cooperatives? Exclusively intended for the PV sector? …*]

2. Particular aspects of interest for MENR regarding RES and CSP (20')

2.1. Complementarity /convergence of Turkish energy policies with the EU's Green Deal plan? [e.g.: *Is the possibility of cooperation mechanisms known or used? What is the foreseen development of green energy in Turkey? Is the EU green ambition a motivator for Turkish energy policy? …*]

2.2. Planned implementation / procurement of solar generation? [e.g.: *Would the installation of CSP plants considered, as three regions present enough DNI? …*]

2.3. Hybridisation of conventional power plants? [e.g.: *As coal is a very important asset in Turkey, could it be hybridised with CSP? …*]

Conclusion: Potential synergies through HORIZON-STE to be discussed at the 26/ 2 event in turkey)

2.4. Manageable and locally produced RES? [e.g.: *Which perception do you have of energy storage? What financial support scheme is foreseen? What is the status of the available public and private funding? What about the national industry champions? …]*

2.5. Increasing energy security through CSP? [*e.g.: Would the use of locally produced energy be a strong argument in the extension of the grid? Is there room in the energy needs of Turkey for CSP? …*]
2.6. Increased potential for being a major energy player in the region [*e.g.: Interest in interconnections? What is the current use of infrastructures and potential development plans? Are there any existing cooperation plans? …*]

1.7.2.3 TEIAŞ

Introduction (10')

- Presentation of ESTELA
- Presentation of HORIZON-STE
- Introduction of the stakeholders and their positions
- Why are we considering Turkey in this project?

1. General perception of Turkish electricity (10')

1.1. Evolution of demand and consumption? [e.g.: *What are the current challenges in the energy system? What do forecasts look like on the short / mid and long-term? …*]
1.2. Evolution of capacity connections? [e.g.: *what is the current use of the infrastructures? What are the development plans? …*]
1.3. Status of interconnections? [e.g.: *what is the current status of interconnections with the EU? Are any new interconnections planned with neighbouring EU countries? Bulk energy purchases? …*]

2. Particular needs and interests of TEIAS regarding RES and CSP (20')

2.1. Status of the TSO legal framework? [e.g.: *Is there any revision in preparation? …*]
2.2. Adaptability of the grid/evolution of the structure? [e.g.: *What are the current considerations regarding the extension of the grid? What would be the potential constraints to extensions /reinforcements of interconnections with, for instance, Bulgaria or Greece? …*]
2.3. Integrating renewables? [e.g.: *Would the interconnection between TEIAS and Greece respectively Bulgaria allow for exports of green energy? Any new developments in preparation to facilitate the integration of renewables to the system? What is the current link between the Mersin CSP tower and the electricity system? …*]

3. Potential synergies through HORIZON-STE (15')

3.1. Manageable RES and storage option? [e.g.: *Which perception do you have of energy storage? …*]
3.2. Possibility to increase capacity and stability through CSP? [e.g.: *Would the use of locally produced energy be a strong argument in the extension of the grid? What would be the installation requirements? Unlicensed production? …*]
3.3. A European energy perspective [e.g.: ?]

1.7.2.4 EMRA

Introduction (10')

Presentations

- visitors and the ESTELA association // thanks for availability
- check on practicalities (recording permission, notes, etc.)
- main purposes of HORIZON-STE, methodology (deepening of our understanding of the national perspective and how / consultation within the CSP sector and report by end of February where could Turkey could receive support from the CSP industry) , global targets, targets regarding Turkey

1. General situation of the electricity market in Turkey (15')

Current situation

1.1. How could the regulatory framework for electricity and gas evolve in Turkey in the mid-term?. *[E.g.: do you perceive the regulatory environment as favourable or not for achieving the objectives set by the government? What would you identify as successes and limitations of the current regulation so far?]*

1.2. Tendering system and remuneration instruments (FiT, Renewable Energy Resources Support Mechanism)? *[E.g.: Would you deem the tendering system as still relevant/effective? What are its strengths and weaknesses? Would you consider that the current remuneration instruments have fulfilled their purpose in an adequate manner? ...]*

Near-future situation

1.3. Potential changes in the regulation in the next 1-3 years *[E.g.: Will the remuneration instruments and tendering schemes be kept or modified in the following years? How? What about other amendments on the Electricity Market Law? ...]*

2. Particular needs and interests of EPDK (20')

2.1. Perceived challenges and opportunities for the future development of the Turkish electricity market? [*e.g.: is there a need for market opening? Ideally, what would favour a bigger mix of electricity providers? What could be the potential changes affecting the schemes for funding renewables ...*]

2.2. Considering the potential of CSP? [*e.g.: Do you see any regulatory barriers that would prevent CSP power plants from being included in the electricity market system? If so, how would you consider that this could be fixed?*

3. Potential synergies with HORIZON-STE (15')

3.1. Increasing the stability and diversity of the electricity market *[E.g.: What is the status of the subsidised long-term loans for RE projects? Would RE cooperatives be considered, and if so, for which energy sources? ...]*

3.2. Possibility to retrofit existing infrastructures *[E.g.: Are there any regulatory barriers for retrofitting existing conventional power plants with solar-thermal technologies (assuming they currently receive any kind of FiT? With the rise of*

VRES in the market, do you think that the current regulation is fit for the different flexibility solutions that could be included in the market (such as storage)…]

1.7.3 Interview guidelines

1.7.3.1 Industry

INTRODUCTION (5')

- Presentation of the interviewer / of ESTELA
- Presentation of HORIZON-STE and of the aim of the interview [e.g.: to gather insights into market conditions for the development of innovative technologies in Turkey, to capitalise on existing assets and favour their development, to optimise investment and return on investment]

1. GENERAL LANDSCAPE (10')
   1.1. Could you please present your company/organisation and its status within the Turkish market? *[e.g.: what is your main field of activity? Do you have project inside and outside Turkey? What is your experience with CSP/CST? What is your specific role? …]*
   1.2. In general, how would you evaluate the framework for developing innovative technologies/businesses in Turkey? *[e.g.: What is very helpful? What is more of a challenge? What would you change? Do you think sometimes that it is easier to develop project in another country? …]*
   1.3. Are you currently / Have you been involved in projects related to CSP/CST (in Turkey or abroad)? If yes, how many? *[e.g.: Do you also collaborate with foreign companies? Which benefit do you see in that? Would you say that the Turkish business framework favours collaborations between Turkish and foreign companies? …]*
2. CAPITALISING ON EXISTING AND DEVELOPING NEW ASSETS (10')
   2.1. According to you, what would be the necessary conditions for an innovative technology such as CSP/CST to really take off in Turkey? *[e.g.: Do you consider receiving enough support for developing your business? What are the signals which motivate you to take risks for business? …]*
   2.2. In your view, which actors are of capital importance to favour the development of a new technology? *[e.g.: Policymakers? The regulatory authority? Financing bodies? Foreign companies? Do you have specific expectations on each of these actors?]*
   2.3. How do you see the CSP/CST market in Turkey in the next 5-10 years? *[e.g.: Do you see any development opportunities? What would be your ideal scenario for the development of the technology? Are you interested in participating in research/FOAK projects? What do you think of knowledge transfer as a process to develop local business? …]*

Conclusion (5')

- How would you summarise the challenges and opportunities you met when trying to promote and increase solar energy usage in Turkey?
- Have you seen any change in the interests of different stakeholders when the Mersin Tower was built?
- What would be the main piece of advice you would give to a company which would like to develop CSP in Turkey?
- Should you have one request to favour the development of CSP/CST in Turkey, what would it be and to whom would it be addressed?
- Is there anything you would like to add?

Thank you for your time and for your help

1.7.3.2 Research

Introduction (5')

- Presentation of the interviewer / of ESTELA
- Presentation of HORIZON-STE and of the aim of the interview [e.g.: to outline the existing potential in turkey for the development of CSP/CST technologies, to facilitate synergies between research and commercial realisation of projects]

1. General landscape: Research in Innovative Technologies in Turkey (10')
   1.1. Could you please present your organisation and the role it plays in research on energy transition in Turkey? *[e.g.: what is the main field of projects which you are running? How do you define your research priorities? ...]*
   1.2. In general, how would you evaluate the research framework regarding innovative technologies in energy in Turkey? *[e.g.: What is working well? What is more of challenge? What would you change? On average, do you think that the proposals you receive are relevant compared to what you perceive is needed? ...]*
   1.3. Are you currently / Have you been involved in projects related to CSP/CST (in Turkey or abroad)? If yes, how many? [e.g.: *What kind of projects or studies are involved with? What usually triggers the launch of these types of projects? Have you seen any evolution regarding the interest for this field in the last ten years? ...]*
2. The Necessary Complementarity of Research and Industry for the Development of CSP/CST in Turkey (10')
   2.1. Currently, how do you see your role in supporting the development of CSP/CST in Turkey? [e.g.: *Do you think that the research/analysis you carry out can be seen as a kick-starter for CSP/CST commercial activities in Turkey? How do you think the dynamic between research and commercial applications could be improved? ...*]

2.2. How would you describe the relationship between research and industry regarding the development of CSP/CST in Turkey? *[e.g.: How do you interact, if at all? Do you share progress or take part in working groups? Are any results from research or studies taken up by the industry afterwards? Do you think that your work can help unlock funding for commercial applications? …]*

2.3. In your view, what would be the best role for CSP/CST in Turkey? *[e.g.: Are current research / studies / energy modelling encompassing CSP/CST? If not, why? What could be done to change that? …]*

CONCLUSION (5')

- How do you see your role in the development of CSP/CST technologies in Turkey in the next 5-10 years?
- Should you have one request to favour the development of CSP/CST in Turkey, what would it be and to whom would it be addressed?
- Is there anything you would like to add?

Thank you for your time and for your help

1.7.3.3 Bank

INTRODUCTION (5')

- Presentation of the interviewer / of ESTELA
- Presentation of HORIZON-STE and of the aim of the interview [e.g.: to understand the financing framework in Turkey for innovative projects, to determine the conditions to facilitate access to funding, to foster high relevance between funding and market opportunities]

1. GENERAL LANDSCAPE: FINANCING INNOVATIVE PROJECTS IN TURKEY (10')

1.1. Could you please present your organisation and the role it plays in financing projects? *[e.g.: what is the main field of projects which you support? Are there specific criteria to fill? How long does it usually take between asking for funding and receiving it? …]*

1.2. In general, how would you evaluate the framework for financing innovative technologies in Turkey? *[e.g.: What is working well? What is more of challenge? What would you change? Would you say that the possibilities and conditions are enough clear for companies? On average, do you think that the applications you receive are relevant? Could there be more of them? …]*

1.3. Are you currently / Have you been involved in financing projects related to CSP/CST (in Turkey or abroad)? If yes, how many? *[e.g.: Can foreign companies also apply for funding? Which benefit do you see in that? Have you seen any evolution regarding the funding of this field in the last ten years? …]*

2. Financing as a Catalyst for Developing Innovative CSP/CST Technologies in Turkey (10')

2.1. How do you see your role in supporting the role of CSP/CST in Turkey? [*e.g.: Do you think that you should only or mainly incentivise Turkish companies? Should you give full support or be a kick-starter for additional support? Do you take Technology Readiness Levels (TRLs) into account when evaluating projects?*]

2.2. In your view, what are the requirements for a project to be sustainable and receive funding? [*e.g.: What are the guarantees you are asking for? Are there any KPIs which you monitor to determine if full funding can be granted? Is the totality of the funding sometimes submitted to results? …]*

2.3. What would be the ideal scenario to facilitate the financing of innovative CSP/CST technologies? [*e.g.: Which stakeholder(s) play(s) a major role in sending positive signals to foster investment (political actors, companies, foreign investors, regulatory authority…)? Would you say that the existence of several small successful projects would trigger more easily funding for bigger projects? Is the presence of foreign companies a good sign for investment? …]*

Conclusion (5')

- How do you see your role in the development of CSP/CST technologies in Turkey in the next 5-10 years?
- Should you have one request to favour the development of CSP/CST in Turkey, what would it be and to whom would it be addressed?
- Is there anything you would like to add?

Thank you for your time and for your help

2 Chapter 2: Italy

2.1 Structure of the document

The "Integrated Country Report – Italy" aims to provide a global and structured approach of the country's profile regarding potential interest in STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2 and WP3 concerning:

- The expressed need for manageable renewable energy sources (RES) energy by the country of focus and the strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.
- The construction of a defined framework for funding and its reception by relevant audiences.
- The evaluation of performance of the funding frameworks.

Section 2.2 summarises the tasks which were carried out, both on the R&I (2.2.1) and industrial (2.2.2) sides. This gives an overview of the intelligence collected and of the key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Proposition of a reshaped funding framework based on feedback from stakeholders and the Implementation Working Group (IWG).
- Dissemination of information about the funding opportunities and impact evaluation.
- Meeting with relevant stakeholders, i.e., at Ministry, Transmission System Operators (TSO) and Regulatory Authority levels, as well as key players from local industries and civil society.
- Brokerage events and joint industry-R&I national event.

A deeper analysis of the context of each country is provided in section 2.3, first for the research section (2.3.1) and then for the industry (2.3.2). Each of these sections provides a global overview of the different factors influencing the development of funding and commercialisation of STE applications. More precisely, it aims to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Italy.

Based on these observations, key findings are drawn in section 2.4, for both research and industry. They highlight encountered challenges and existing opportunities and finally draws a picture of the potential synergies between R&I and industry structures.

Last but not least, section 2.5 suggests strategic actions to continue opening doors for STE in Italy, from a research and industrial point of view. It finally offers an overarching approach to further support the development of STE in Italy, combining R&I and industry perspectives to offer thorough advice.

2.2 Summary of undertaken activities

Italy has been under the scope of analysis from September 2021 until May 2022. The Covid-19 global pandemic has slowed down the working process. Notably, ESTELA has collaborated with the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) regarding the information related to R&I, to maximise impacts and meaningful results. The following chapters will describe the work undertaken in Italy and analyse the challenges and opportunities met in the country.

2.2.1 R&I methodology

To have a wide overview of the R&I landscape of Italy, the following activities were carried out or are being planned:

List of activities	Timeline
Documentation phase	Phase 1 Sept. 2021 – Dec. 2021
Aim: To collect the information available about R&I in Italy related to CST technologies (stakeholders, research centres, funding sources,..)	
Description:	ENEA is the Italian partner in the HORIZON-STE project and taking into consideration the synergies between this Integrated Country Report and the content of the National Concept Note of Italy to be elaborated within the framework of WP3 in the European SFERA-III project, people responsible for that Concept Note were contacted by ENEA to get all the information available about R&I in the Italian CST sector. People from MiTE, MUR, Eni, Fata, Sol.In.Par., Ansaldo, Brembana&Rolle, A.C. Boilers, Elianto, and Magaldi were also contacted to get several documents with information about industries, research centres, research facilities, and funding sources in Italy for R&I activities related to CST technologies and applications.
Processing of information and writing of report	Phase 2 Sept. 2021 – May 2022
Aim: To write the sections devoted to R&I in this Integrated Country Report of Italy	
Description Desk research:	All the information collected during the documentation phase was analysed and processed by ENEA in order to get the R&I landscape of Italy for CST technologies and applications, especially those directly related to the SET Plan for CSP. The updated list of national and European R&I projects prepared by ENEA in 2022 was also analysed to see the R&I activities currently underway in Italy and the topics covered. It was also included in this analysis the information collected by ENEA from Italian entities when preparing the Deliverable D1.4 ("Report on options for financing instruments and schemes") of HORIZON-STE project.

2.2.2 Industry

2.2.2.1 Foreseen activities and implementation challenges

To support a wider use of STE applications in Italy, ESTELA designed a general process unfolding in three steps with flexibility to adapt to the specific country challenges:

Phase 1	
Background research and first meetings	
General aim	To understand the need for manageable RES energy and Italy's strategies for the development of RES in the country and for import / possible changes in the relevant framework conditions
Encountered challenges	– To find the right interlocutor – Low answer rate to interview requests – Mixed information received from different interlocutors
Applied mitigation	– Help from ENEA to identify relevant stakeholders – Send two reminders when facing unanswered requests – General translation of official documents from Italian to English – Confrontation of different sources with the official source
Phase 2	
Brokerage Event	
General aim	Assessment and presentation of potential solutions using CSP/STE
Encountered challenges	– Covid-19 global pandemic – Overload of political agenda due to changing of the President of the Italian Republic
Applied mitigation	– Digging into the potential hybridisation of CSP for hydrogen production – Promoting cross-border projects opportunities
Phase 3	
Joint National Event	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	– Outbreak of covid-19 global pandemic – Not enough data collected yet
Applied mitigation	– Awaiting the end of the pandemic to evaluate the possibilities

2.2.2.2 Carried out activities

List of activities	Timeline
BACKGROUND RESEARCH	Phase 1 Sept.-Dec. 2021
Aim: To collect relevant information to better understand the energy landscape in Italy, the potential challenges for the development of STE and the needs of the country	

List of activities	Timeline
Description Desk research: Collection of information based on available content on official websites (Ministry of the Ecological Transition (MiTE), ENEA, Italian Regulatory Authority for Energy, Networks and Environment (ARERA), ENI S.p.A., TERNA S.p.A., etc.) academic studies or reports by consultancies. Stakeholder mapping: Analysis of the specific relevant departments and actors for each identified target group Exchanges with ENEA on relevant contacts and existing knowledge of the local situation	
PRELIMINARY TALKS	Phase 1 Sept.-Dec. 2021
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable RES, the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions	
Description Ideally, this phase aims to establish a first contact with the three key stakeholders in Italy regarding energy policy, namely the TSOs, the Ministry and the Regulatory Authority. TSOs: Interview with TERNA S.p.A. Ministry: It wasn't possible to schedule an interview with MiTE. However, ESTELA carried out research on material from official Italian government publications[24], which was necessary to understand the structure of the Italian policies for the introduction and the deployment of CSP. Industry: It wasn't possible to schedule an interview with ENEL Green Power, but was invited to the joint national industry and R&I event in Italy. Interview with ENI S.p.A. Research: Interview with ENEA	
PHONE INTERVIEWS	Phase 1 Sept.–Dec. 2021
Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of Italian's energy strategy and potential need for manageable RES	
Description ENEA: Interview with a representative of ENEA, also Board Member of ESTELA	
BROKERAGE EVENT	Phase 2 Sept.–Dec. 2021
Aim: To have a broad overview of STE perspectives in Italy through existing and potential solutions using STE, from both the R&I and industry sides.	
Description A series of online meetings with national stakeholders were held as a mitigation measure due to the COVID-19 pandemic restrictions.	
NATIONAL EVENT	Phase 3 June 2022
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the support of Italian STE industries involved in foreign STE projects and concentrated solar thermal technologies for industrial heat. To focus on possible synergies and macro-economic value.	

[24] See: https://www.mite.gov.it/

List of activities	Timeline
Description The joint industry and R&I national event took place on 14 June 2022 in a hybrid format, online via Zoom and in person at the iH Hotels Roma Cicerone, Rome, Italy. The event included a technical visit to the solar platform of the ENEA Casaccia Research Center. The main conclusions and highlights of the event will be reported in the Deliverable 4.7 “Proceedings of the Joint Industry and R&I Events”.	

2.3 Overview of the context in Italy

2.3.1 R&I landscape

Italy views the SET Plan as a fundamental instrument for meeting the new challenges posed by decarbonisation and agrees with the role the EC has assigned to it in setting the objectives of the present Plan. Since the SET Plan was first introduced, Italy has progressively aligned its objectives and priorities for public investment in research and innovation in the energy sector with those of the SET Plan.

Italian R&I activities are coordinated by public institutions at national level, but the implementation occurs at national and regional level[25].

The high-level political governance of R&I is linked to two main bodies: the Council of Ministers and the Inter-ministerial Committee for Economic Planning and Sustainable Development (CIPESS)[26]. By approving the National Research Programme (PNR) – the strategic Italian R&I policy document – Inter-Ministry Committee for Economic Planning allocates overall financial resources to public research performers.

The main ministries involved in funding energy R&I are the Ministry of University and Research (MUR)[27] and the Ministry of Ecological Transition (MiTE)[28]. Both have been tasked with coordinating the SET Plan. Invitalia (the National Development Agency)[29] manages all national incentives for the creation of new companies and innovative start-ups. ENEA coordinates the National Energy Technology Cluster, a public-private research partnerships involving more than 90 entities. The main public institutions conducting energy research are ENEA, the National Research Council (CNR)[30] and Research on Energy Systems (RSE)[31]. Furthermore, energy-related R&I is conducted at many universities and technical high schools.

The PNR[32] is the framework within which the strategic research guidelines are outlined. On 15 December 2020, the CIPESS approved the 2021-2027 PNR, the result of a wide-ranging and in-depth debate initiated by the MUR with the scientific community, the state and regional administrations, and extended, for the first time, through a public consultation. The result is a participatory and dynamic multiannual framework programming tool, designed to contribute to the achievement of the United Nation Sustainable Development Goals, the EC's core priorities, the 2021-2027 EU Cohesion Policy objectives, and the Next Generation EU (NGEU) fund. The 2021-2027 PNR is divided into six major areas that reflect the six clusters of Horizon Europe, the 2021-2027 European

[25] Constitutional amendments in 2001 provided a new framework for sharing regulatory competences, including energy, between the state and the regions.

[26] https://www.programmazioneeconomica.gov.it/competenze-cipess/

[27] https://www.mur.gov.it/it

[28] https://www.mite.gov.it

[29] https://www.invitalia.it

[30] https://www.cnr.it

[31] https://www.rse-web.it

[32] Legislative decree n. 204/1998.

Union Framework Programme for Research and Innovation and consider the areas of the National Strategy for Smart Specialisation[33]. The area related to energy innovation corresponds to cluster 5 of Horizon Europe: Climate, Energy and Mobility[34].

The COVID-19 pandemic has caused delays in achieving the targets set through the various research programmes, not just related to energy innovation. Limited access to research infrastructures and difficulties in procuring materials have lengthened the time needed to carry out experiments. As part of a wide-ranging response, the aim of the EU Recovery and Resilience Facility is to mitigate the economic and social impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient, and better prepared for the challenges and opportunities of the green and digital transitions. The Facility, a temporary recovery instrument, allows the Commission to raise funds to help Member States implement reforms and investments that are in line with the EU's priorities and that address the challenges identified in country-specific recommendations under the European Semester framework of economic and social policy coordination. Each Member State submitted its own NRRP - National Recovery and Resilience Plan (Piano Nazionale di Ripresa e Resilienza, PNRR)[35].

The respective Plan is a package of investments and reforms worth € 191.5 billion and is divided into 6 missions, i.e., main thematic areas on which to intervene, identified in full coherence with the 6 pillars of the NGEU. The missions are divided into components, areas of intervention that address specific challenges, which in turn are composed of investments and reforms. Mission 2 "Green revolution and ecological transition"[36], led by MiTE, has 31% of the total resources (€ 59.46 billion), and component 2 of mission 2, "Renewable energy, hydrogen, grid and sustainable mobility", aims to contribute to the achievement of the strategic decarbonisation objectives through five lines of reforms and investments. In this context a first line of investment aims to increase the share of energy produced from renewable sources, the third project line is reserved for hydrogen, promoting its production, distribution and end uses in line with EU and national strategies, and the fifth line aims to promote the development in Italy of competitive supply chains in the fastest-growing areas, which will make it possible to reduce dependence on imported technologies and, indeed, to make them a driver of employment and growth. Furthermore, impacts on energy innovation will come also from investments and reforms in mission 4 "Education and research" (€ 30.88 billion), led by MUR. Indeed, the second component of mission 4 aims at increasing the growth potential of the economic system by leveraging investments in research and development. It looks at basic, applied research and technology transfer to strengthen the research system along the different stages of technological maturity, by acting systemically on the lever of investments in R&I. In this context, investments are envisaged

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[33] See: https://www.agenziacoesione.gov.it/lacoesione/le-politiche-di-coesione-in-italia-2014-2020/strategie-delle-politiche-di-coesione/strategia-nazionale-di-specializzazione-intelligente/.

[34] Available in full here: https://www.mur.gov.it/sites/default/files/2021-08/5.AllegatoEsteso_Clima.pdf

[35] https://italiadomani.gov.it/en/home.html

[36] See: https://www.mite.gov.it/pagina/missione-2-m2-rivoluzione-verde-e-transizione-ecologica

for the strengthening of research infrastructures, the creation of "national R&I networks" in certain key enabling technologies, and the creation of "innovation ecosystems" around "local R&I systems". To address the challenges of this component, the measure provides for public support (through incentives) to the participation of Italian companies in strategic value chains through initiatives such as Important Projects of Common European Interest (IPCEI) and Partnerships in Research and Innovation within Horizon Europe. Related to energy innovation it is worth to mention: IPCEI Battery 1, IPCEI Battery 2, IPCEI Hydrogen, and Clean Energy Transition Partnership.

2.3.1.1 Italy's R&I support programmes

The National Electric System Research (RdS)[37] programme promotes R&I activities aimed at reducing the cost of electricity for end users, improving system reliability and service quality, reducing the impact of the electricity system on the environment and health, enabling the rational use of energy resources, and ensuring that the country has the conditions for sustainable development. The activities are financed through the "Fund for financing research and development activities of general interest for the national electricity system" set up at the *"Cassa per i Servizi Energetici e Ambientali"*[38] and fed by the revenue from component A5 of the electricity supply tariff. The amount of this component is established periodically by the ARERA[39]. The MiTE elaborates a three-year plan which considers the energy strategy in the medium and long term, the European programmes and the commitments and agreements signed by the government in the field of energy; the plan is initially submitted for public consultation and, after receipt of comments and indications, is amended and published in its final version with the consent of the ARERA. The latter sets the required regulations to guarantee the necessary funding (i.e., sets the portion of system charges accordingly). For the portion of the programme dedicated to the total benefit of users of the national electricity system (i.e., financed up to 100%), specific contracts can be awarded to publicly owned research centres or public competitions can be organised. At the light of the published three-year programme, the interested parties submit coordinated proposals that are evaluated by a pool of independent experts appointed by the Ministry. For the portion of the programme open to specific interests, a conventional competition scheme is applied. Project monitoring is carried out on a yearly basis and at the end of each three-year period. For the implementation of the research activities defined in the three-year plan, the MiTE enters into a Programme Agreement with the three entrusted entities RSE S.p.A, ENEA and the CNR. The latter then draw up three-year implementation plans, broken down by research projects, which will form the technical specifications of the agreement. The three-year plan for 2019-2021 (available resources equal to 210 M€), focused on new research objectives in line with the SET Plan and the involvement in Mission Innovation, is facing some delay due to COVID-19 pandemic. The new three-year plan for 2022-2024 is currently under consultation (available resources equal to 210 M€). The ex-ante evaluation of each research project proposal is carried out by a pool of experts as well as yearly

[37] *See: http://www.ricercadisistema.it/#/*

[38] *See: https://www.csea.it*

[39] *See: https://www.arera.it/it/index.htm#*

monitoring, during the projects' development. Final project assessment ex-post considers the entire three-year span.

The National Operational Programme "Research and Innovation" (PONRI) is the instrument with which Italy contributes to the implementation of the EU's cohesion policy in favour of its most disadvantaged territorial areas. The 2014-2020 PONRI is managed by MUR, with a total budget of 1,286 million euros, of which 926 million are allocated by EU through the European Regional Development Fund (ERDF) and the European Social Fund and 360 million from national co-financing. The 2014-2020 PONRI proposes innovative measures and actions related to the thematic priorities outlined in the 2015-2020 PNR and the strategic lines identified in the National Strategy for Intelligent Specialisation and with regional operational programmes and smart specialisation strategies. It is developed through three priority axes of intervention:

- Axis I - Investment in Human Capital, co-financed by the European Social Fund, with a total amount of € 317 million.
- Axis II - Thematic Projects, co-financed by the ERDF, with a total amount of approximately EUR 825 million. The Axis aims to strengthen research infrastructures, capacities to develop excellence in research and innovation and to promote centres of competence, particularly those of European interest.
- Axis III - Technical Assistance, co-financed by the ERDF, with a total amount of 47 million euros, aims to ensure the designated authorities, the necessary support of the functions assigned to them and ensure the proper management, control, communication, and evaluation of the PONRI.

Within Axis II it is worth to mention the National Energy Technology Cluster. In August 2017, the MUR (by way of Directorial Decree No 1853 of 26 July 2017) approved the setting-up of public-private research partnerships. The initiative is coordinated by ENEA and has so far attracted more than 90 public and private entities. It follows the priority European, national, and regional technological trajectories, which are characterised by differing technology readiness levels, and will play a part in reaching the research planning targets set out in the SET Plan, the National Energy Strategy, the National Research Programme, the Smart Specialisation Strategy, and the industry 4.0 initiatives, and through the involvement in Mission Innovation. Two pilot projects are currently running and one of them is related to CSP: New Sustainable Energy Mix (NeMESi), led by ENI S.p.A. with a budget of 1.2 M€.

PONRI is based on competitive calls. The ex-ante evaluation of each research project proposal is carried out by a pool of experts, identified by MUR, as well as yearly monitoring, during the projects' development. Final programme impact assessment ex-post considers the entire programme duration. The draft plan of 2021-2027 PONRI is still under a consultation process with a provisional budget of 5.6 billion euros.

In the coming years, public funds in the order of EUR 765 million are foreseen for R&I through 3 pillars:

a. National Electric System Research (RdS). A national plan (Piano Triennale) 2022 to 2024 with EUR 210 million focuses on R&I for decarbonisation (EUR 106 million) and digitalisation (EUR 104 million). Decarbonisation includes support in hydrogen, storage, photovoltaics, solar thermal, wind and geothermal energy. Digitalisation includes areas such as smart grids and integration of renewables into the electricity grid.

b. Mission Innovation (MI). In February 2021, the Ministry of Economic Development (MiSE) issued a Ministerial Decree that establishes a 3-year Programme Agreement between ENEA and MiSE (now with MiTE) to carry on research activities in line with Mission Innovation priorities. The decree, with a total budget of 35.8 million euros, allocates 17.5 million to hydrogen, 9.7 to smart grid and 8.6 to materials. ENEA presented an operation plan involving the CNR, RSE, and the Italian Institute of Technology. Although within this context CST has not been considered, another EUR 395 million will be allocated for R&I supporting public institutions and with two calls for tenders. Hopefully, CST will be supported through the coming decree expected by the end of 2022.

c. National Recovery and Resilience Plan (NRRP). The NRRP foresees EUR 160 million (2022 to 2026) for R&I in hydrogen and fuel cells. The Ministerial Decree issued by the MiTE in December 2021, allocates 110 million euros to implement investment 3.5 "Hydrogen Research and Development", foreseen under Mission 2 "Green Revolution and Ecological Transition", Component 2 "Renewable Energy, Hydrogen, Grid and Sustainable Mobility" of the NRRP. ENEA is negotiating a Programme Agreement with MiTE based on a 2022-2025 Operational Research Programme. ENEA will oversee carrying out the research activities, as they will be identified in the Operational Research Programme, in collaboration with the CNR and RSE, as co-beneficiaries. This could open some opportunities for R&I on thermochemical hydrogen production supported by CST.

2.3.1.2 Existing R&I activities

Italy is deeply committed to the CSP Implementation Plan execution. Italy was strongly involved in the Temporary Working Group, in which the R&I topics were decided by a wide representation of European stakeholders and has also been engaged in the IWG since its establishment after the publication of the Implementation Plan (IP). Three national projects were initiated since the IP launch, and one started during its elaboration. Furthermore, Italy is involved in the two actions that are currently more directly related to the execution of the IP: the “CSP-ERANET” project and the “HORIZON-STE” project, which see the MUR as partner and ENEA as partners, respectively.

Several Italian organisations have been participating in many EU-funded research and innovation projects under the Horizon 2020 programme. Starting from 2017, 11 EU projects (6 of which with an Italian coordinator) have been active with a total budget for the Italian partners of nearly 21 M€. The key data of these projects are reported in detail in Figure 9 and in Table 5. At national level, the financial contribution is around 21 M€, in line with that coming from EU.

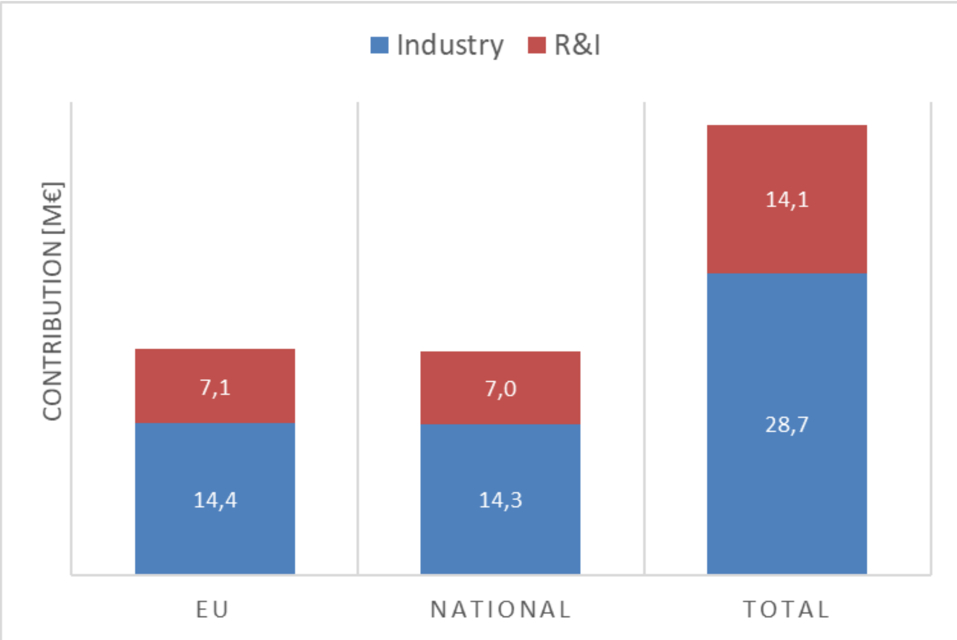

Figure 9: Funding of CSP research projects involving Italian partners (since 2017)

It is important to point out that a change of pace has taken place starting from 2017, when the concentrated solar energy returned among the strategic issues covered by the RdS programme promoted by the Ministry of the Economic Development (today, by the MiTE). Within this framework, in December 2021 ENEA has completed a three-year research project, which was dedicated to the study of several innovations related to heat transfer fluids, coatings for receiver tubes, self-cleaning mirrors and advanced TES systems. CSP has also been included in the draft plan for the next three-year period of the RdS programme, which is currently under public consultation. The activities envisaged in the current draft build on the results of the above-mentioned project, aiming at increasing the TRL of the developed innovations.

However, the national projects cover a much broader range of activities, mostly system- rather than technology-oriented, and see the involvement of industrial partners, which substantially contribute to fund the R&I activities.

ENEA, together with various national industrial entities (ENI S.p.A., Magaldi Power, Ese Engineering, C. & C. Consulting Engineering etc.), is strongly engaged in research activities for the development of innovative components and plant solutions, which aim at simplifying the installation, increasing the operational efficiency and improving the reliability of CSP plants, while reducing their construction and O&M costs (SOLARGRID project funded by Ministry of University and Research). It is worth mentioning here the national project NeMESi, which started in January 2017 with a duration of 48 months, with a co-funding of MUR trough the national technology cluster for energy. The project aimed at analysing the integration of concentrated solar systems including TES with fossil and biomass-based systems to produce electricity and/or process heat in industrial/commercial/residential contexts.

Finally, the WOW-SUN project, funded within the ERDF of Sicily Region, was recently started (January 2021). The project, which involves several Italian industrial partners

(Ecoprime Italia, VENTUS ARTS, ARITEC, CO.ED.IN, C&C Consulting, IDRONORD) and two research institutions (ENEA and the Euro-Mediterranean Institute of Science and Technology), has a duration of 30 months and is aimed at developing, realising, and testing an innovative thermal storage system (real scale, about 20 MWh) that should serve as integration element between a PV and CSP plant. The TES system is a molten salt thermocline tank, which can be charged by both electricity and thermal energy, to integrate the operation of CSP and PV plants. The total project budget is 4 M€, with a public co-funding of 3.4 M€.

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Italian Industrial Partners	Italian R&I Partners
EU	Advanced materials solutions for next generation high efficiency CSP tower systems	NEXTOWER	ENEA – (IT)	Jan 2017 - Jun 2021	Walter Tosto SpA	ENEA; Politecnico di Torino; Università degli Studi di Roma “La Sapienza”; CERTIMAC; CALEF
EU	Advanced Materials technologies to QUADRUPLE the Concentrated Solar Thermal current POWER GENERATION	IN-POWER	LEITET – (ES)	Jan 2017 - Jun 2021	Kolzer SRL	ENEA
EU	SOlar Calcium-looping integRAtion for Thermo-Chemical Energy Storage	SOCRATCES	UNIVERSIDAD DE SEVILLA – (ES)	Jan 2018 - Dec 2020	---	Politecnico di Torino; CNR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Italian Industrial Partners	Italian R&I Partners
EU	Solar Facilities for the European Research Area - Third Phase	SFERA-III	CIEMAT – (ES)	Jan 2019 - Dec 2022	---	ENEA
EU	Supercritical CARbon dioxide/Alternative fluids Blends for Efficiency Upgrade of Solar power plants	SCARABEUS	Politecnico di Milano – (IT)	Apr 2019 - Mar 2023	Exergy SpA	Politecnico di Milano; Università degli Studi di Brescia
EU	HIgh storage density solar power plant for FLEXible energy systems	HIFLEX	KT-KINETICS TECHNOLOGY SPA – (IT)	Sep 2019 - Aug 2023	KT-Kinetics Technology SpA; BARILLA G. E R. FRATELLI SPA; NEXTCHEM SpA (*)	---

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Italian Industrial Partners	Italian R&I Partners
EU	Solar Heat for Industrial Process towards Food and Agro Industries Commitment in Renewables	SHIP2FAIR	FUNDACION CIRCE CENTRO DE INVESTIGACION DE RECURSOS Y CONSUMOS ENERGETICOS - (ES)	Apr 2018 – Jun 2023	RINA CONSULTING SPA; MARTINI & ROSSI SPA	FONDAZIONE LINKS - LEADING INNOVATION & KNOWLEDGE FOR SOCIETY
EU	Forthcoming Research and Industry for European and National Development of SHIP	FRIENDSHIP	CEA - (FR)	May 2020 –Apr 2024	RINA CONSULTING SPA	
EU	SOLAR based sCO2 Operating Low-cost plants	SOLARSCO2OL	RINA CONSULTING SPA – (IT)	Oct 2020 - Sep 2024	RINA CONSULTING SpA; FRANCO TOSI MECCANICA SpA; NUOVO PIGNONE SRL; OCMIOTG SpA	Università degli Studi di Genova

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Italian Industrial Partners	Italian R&I Partners
EU	Hydrogen PROduction by MEans of solar heat and power in high TEmperature Solid Oxide Electrolysers	PROMETEO	ENEA – (IT)	Jan 2021 - Jun 2024	SNAM SpA; NEXTCHEM SpA	ENEA; FONDAZIONE BRUNO KESSLER
EU	DEmonstration of CSP coupled wIth advaNced desAlinaTion system in the gulf regION	DESOLINATION	Politecnico di Milano - (IT)	Jun 2021 – May 2025	NUOVO PIGNONE SRL;	Politecnico di Milano; Università degli Studi di Brescia
N (MiSE)	Solare termodinamico		ENEA – (IT)	Jan 2019 - Dec 2021	---	ENEA; Politecnico di Milano; Politecnico di Torino; Università Campus Bio-Medico di Roma; Università degli Studi di Roma “Tor Vergata”; Università degli Studi di Palermo; Università

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Italian Industrial Partners	Italian R&I Partners
						degli Studi di Perugia; Università degli Studi di Roma "La Sapienza"
N (MUR)	Nuovo Mix Energetico Sostenibile (New Sustainable Energy Mix)	NeMESi	ENEA – (IT)	Jan 2017 - Dec 2020	ENI S.p.A.; NUOVO PIGNONE SRL	ENEA; CNR; EnSIEL; Ricerca sul Sistema Energetico SpA
N (MUR)	Sistemi sOlari termodinamici e fotovoLtaici con Accumulo Per coGeneRazIone e flessibilità Di rete (Thermodynamic and photovoltaic solar systems with storage for	SOLARGRID	ENEA – (IT)	Mar 2018 - Aug 2021	ENI S.p.A.; ENI mediterranea Idrocarcuri SpA; Horizon SRL; Idea srl; Magaldi Power S.p.A.	ENEA; Politecnico di Milano; Università degli Studi di Firenze; Università degli Studi di Palermo; Università degli Studi di Siena

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Italian Industrial Partners	Italian R&I Partners
	cogeneration and network flexibility)					
N (MUR)	European Parabolic Trough with Molten Salt	EuroPaTMoS	DLR - (DE)	Feb 2021 - Jan 2024	---	ENEA
N (Sicily Region)	With Or Without the SUN	WOW SUN	C.&C. Consulting Engineering SRL – (IT)	Jan 2021 - Jul 2023	C.&C. Consulting Engineering SRL; Idronord SRL; CO.ED.IN. SpA; Ventus Art SRL; Aritec SRL; Ecoprime Italia SRL	ENEA; I.E.ME.S.T. Istituto Euro - Mediterraneo di Scienza e Tecnologia

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Italian Industrial Partners	Italian R&I Partners
N (MUR)	INNOVATIVE SOLAR MICRO-THERMAL ENERGY STORAGE WITH HIGH-POWER DENSITY	InnoSolPower	Pars Makina ltd – (TR)	Feb 2021 – Jan 2023	---	Università degli Studi di Pisa

Table 5: R&I Projects with involvement of Italian stakeholders since 2017 relevant to the CSP IP

Despite the issues in the deployment of commercial plants in the country, research activities on CST technologies are actively progressing and new research infrastructures being built in Italy. Most of the research infrastructures are currently owned by ENEA, which started developing significant facilities during the decade 2000-2010, within the first large-scale research programme on CSP in Italy. After that experience, new research projects, mostly funded within the framework programmes of the EU and national/regional initiatives, have seen the participation of an increasing number of other Italian players, including universities, research and technology organisations, and industry, also leading to the development of new research facilities. Overall, today the infrastructure and research activities are mostly in the middle TRL levels (from TRL3 to TRL6), with a rather comprehensive scope covering, from material research to component and system development, all the main aspects of the CST technology: solar field and receivers, TES, power block, heat transfer and storage materials. Table 6 below summarises some of the most relevant research infrastructures currently available in Italy.

Name	Location	Owner	Description
PCS (Prova collettori solari)	Rome - Casaccia Research Centre	ENEA	On-sun experimental rig aimed at testing full-size elements of linear parabolic trough collectors using high temperature molten-salt as heat-transfer fluid under actual operating conditions. This infrastructure also hosts several prototypes of innovative components for MS CSP plants, which take advantage of the PCS auxiliary equipment to store, pump, heat and cool molten salts in the range 290-550°C.
ORC-Plus TES prototype	Rome – Casaccia Research Centre	ENEA	Prototypal single-tank indirect TES system using a low-melting ternary molten salt mixture as heat storage medium and thermal oil as heat transfer fluid. Charging and discharging are carried out through two oil-salt heat exchangers embedded in the lower and upper part of the tank, respectively. The system operates in the range 180-300 °C and has a nominal capacity of 200 kWh.
REslag thermocline TES	Rome – Casaccia Research Centre	ENEA	Prototypal single-tank packed-bed thermocline TES system using molten salts as heat transfer fluid and processed steel slags as solid heat storage material. The active storage volume of the tank has a diameter of 1 m and a height of 3 m and is loaded with 4.1 t of slag pebbles. The nominal storage capacity of the system is approximatively 475 kWh. The facility

Name	Location	Owner	Description
			allows to test the TES system under charging and discharging conditions with molten salt mass fluxes in the range 0.45-1.5 kg s^{-1} m^{-2} ad feed temperatures in the range 290-550°C.
MoSE (Molten Salt Experiences)	Rome – Casaccia Research Centre	ENEA	Molten salt loop that allows to perform off-sun experiments with molten salt streams up to 550 °C. The facility allows to carry out several types of tests, such as: dynamic corrosion tests on structural material samples; analysis of the performance of innovative molten-salt-heated/cooled component (e.g., heat exchangers, fired heaters, chemical reactors, etc.). The system operates with a maximum flowrate of 1.2 kg/s and 60 kW of heating power.
OMSoP Dish	Rome – Casaccia Research Centre	ENEA	Parabolic dish facility (12 m diameter) Including a power block based on a micro gas turbine operating with air up to 800-900°C.
ESOL (ENEA Solar Collector Optics Lab)	Rome – Casaccia Research Centre	ENEA	Laboratory providing optical characterisation of solar collectors according to international guidelines and developing advanced tools for on-field measurement of the solar reflectance and the 3D shape of reflecting surfaces.
CoMETHy	Rome – Casaccia Research Centre	ENEA	Pilot hydrogen production plant based on an innovative solar-heated reforming process. The core of the plant is an integrated membrane reactor designed for the low-temperature (450-550 °C) steam reforming of several carbonaceous feedstocks like methane, biogas and (bio)ethanol. The process heat is provided to the reactor by using molten salts as heat transfer fluid, which allows easy coupling with consolidated CST technologies. The pilot plant is currently coupled with ENEA's MoSE facility and has a capacity in excess of 2 Nm^3/h of hydrogen.
Elioslab	Naples – Portici Research Centre	ENEA	Solar furnace (30 kW_{th}), equipped with primary/secondary reflector and cavity receiver aimed at testing and validating innovative technical solutions for the

Name	Location	Owner	Description
			production and use of high temperature solar heat.
ENEA-SHIP	Rome – Casaccia Research Centre	ENEA	ENEA-SHIP is a real scale Linear Fresnel solar collector (200 kW_{th}), using diathermic oil as HTF, mainly equipped with electric heaters, air coolers, buffer, recirculation pump, to test new technical solutions for the generation of heat at medium temperature levels.
Solar Lab	Palermo	University of Palermo	Linear Fresnel pilot plant with 3000 m^2 of extension mainly devoted to the demonstration and testing of new solar components and technologies. The solar field (200 KWth) has an aperture of about 480 m^2. An environmentally friendly bioderivate oil is used as HTF. The plant is equipped with a 8 m^3 thermocline TES system using a ternary molten salt mixture as heat storage medium. The plant also supplies thermal energy to a 23 kW LiBr chiller and a 10 kW ORC generator, which are serving the demand (electricity, heat, cold) of the close building.
Ripasso Energy dish-Stirling unit	Palermo	University of Palermo	Dish-Stirling unit with a diameter of about 12 m and an effective aperture area of 101 m^2. The PCU consists of a cavity receiver coupled with a Stirling engine, an alternator and a cooling system.
Megaris	Salerno	CNR - STTEMS	Hybrid TES system for residential applications. It consists of a hot bubbling fluidised combustor 0.29x0.29 m (20-40 kW, bed temperature up to 950°C) coupled with a Stirling Engine 0.5 kW and a sun simulator 10kW and fuelled with biomass or simulated biogas for testing performance of CHP unit integrating different RES and tailoring the TES
DIFBAR	Salerno	CNR - STTEMS	Fluidised bed solar receiver/reactor coupled with a double pipe heat exchanger and with a 7/10 kW sun simulator (bed temperature up to 1200°C). Proof of concept of a novel fluidised bed reactor finalised to solar-driven chemical processes especially

Name	Location	Owner	Description
			based on two-step thermochemical cycles.
Test bench for thermochemical metal oxide cycles	Torino	Politecnico di Torino	Micro-reactor and dish system for on-sun tests of thermochemical metal oxide cycles. The experimental set-up is designed to test powder/pellet materials for kinetic studies on the thermochemical reduction of CO_2 and H_2O. The bench allows to perform user-customised fully automatic redox cycles with imposed gas mixtures and controlled humidity in a wide range of temperatures (up to 1800°C).
STEM (Solar Thermo Electric Magaldi Unit)	San Filippo del Mela (Sicily)	Magaldi Power	Modular steam generator units (SGU) based on a beam-down central receiver architecture, which can be combined together to produce the superheated steam flow rate (at around 500 °C), to be used to generate electricity or as process heat. The receiver is based on a fluidised bed technology: 270 tons of fluidised sand, at an operating temperature of 550-650 °C, are used to effectively transfer and store the solar thermal energy (up to 8.2 MWh_{th} per module).
Soltigua Fresnel plant	Gambettola (Emilia Romagna)	Soltigua	Experimental platform to test new solutions for linear Fresnel plants. The solar field has a 2,640 m^2 size and a power capacity of 1.2 MW at a steam outlet temperature of 180°C. Steam is produced by two collectors' fields working in parallel, both directly (Direct Steam Generation) and indirectly (by a thermal oil solar circuit). The solar integration takes place mostly with steam to air heat exchanger, by increasing up to 160°C the temperature of the ambient air used in the dryer.
FREeSun	Noto (Sicily)	FERA Group	LFR DSG collector, 64 m long for a collecting surface of 768 m^2. Peak power is 400 kWth. Operating temperature is 260 °C at 60 bar.

Table 6: CSP/T research infrastructure in Italy

2.3.1.3 National and international cooperation

Italy's energy research innovation activities are closely coordinated with the SET Plan in the perspective of the full implementation of the Energy Union at European level. In coming years in fact, EU R&I resources will be increasingly allocated to the priority key-actions identified under the SET Plan, as already happened for the Horizon 2020 Programme for Research and Innovation. Indeed, Italy has decided to oversee all the working groups set up for organising the IPs concerning the ten key action areas. The MiTE and the MUR have been tasked with coordinating the SET Plan. The national representatives of each working group have, in turn, set up 'consultation groups' made up of representatives from the industrial, research and academic spheres, which can contribute significantly to the drafting and updating of the IPs. During the extensive work in drawing up the Implementation Plans, Italy has been particularly active in cooperating with other Member States to identify priorities and recommendations with respect to financial requirements.

Italy strongly supports the Clean Energy Transition Partnership (CETP), European Partnership under Horizon Europe R&I Programme. The co-funded CETP aims at addressing the challenge of a climate-neutral economy through R&I in clean energy technologies thus accelerating the clean energy transition. CETP builds upon the work of the SET Plan Implementation Working Groups, their Implementation Plans and related earlier/running co-funded actions between SET Plan countries and the EC, e.g., ERA-NETs and the Joint Programming Initiative Urban Europe. Within this context Italy is leading the Challenge 2: Enhanced Zero Emission Power Technologies.

ENEA is one of the founders of the European Energy Research Alliance (EERA), a membership-based, non-profit association of European public research centres and universities active in low-carbon energy research. EERA's members work together in joint research programmes, which are aligned with the priorities of the SET-Plan. Italy participates in all the 18 JPs. The Joint Programme dedicated to CSP, launched in November 2011, see the participation of the following Italian entities: the ENEA, CNR, and Bruno Kessler Institute as full members, and University of Palermo, University of Naples Federico II, and University of Florence as associated partners. Furthermore. ENEA leads one of the six Sub-Programmes (TES for CSP plants) of the JP on CSP.

Considering EU efforts and commitment in Mission Innovation, the Italian National Energy and Climate Plan (NECP) establishes an integrated approach for both MI and the SET Plan to be implemented by the Italian Government in designing the clean tech R&I governance framework. Within this context, Italy considers the launch of Mission Innovation Phase 2 an opportunity to accelerate public and private investments in clean energy research and innovation. The Italian participation can offer a significant contribution in facing problems such as the low private sector participation in R&I investment in the energy sector and the high degree of fragmentation among the R&I actors.

The MiTE has been appointed by the Italian Prime Minister's Office, as lead Administration of the Italian participation in Mission Innovation and, thus, has implemented two levels of governance. The first one with the main Ministries involved: the Ministry of Foreign Affairs and International Cooperation, the Ministry of Economy and Finance and the MUR. The second one with the public R&I institutions which carry out energy-related research such as the National, ENEA, the CNR and RSE S.p.A which are already committed in the context of Programme Agreements with MiTE. Other important contributions are coming also from the National Institute of Oceanography and Applied Geophysics and the Italian Institute of Technology. An important role will be also played by the regional governments and the scientific community (universities, R&I labs).

Italy joined Mission Innovation Phase 1 in 2015, and under this umbrella, set up the hydrogen task force, gathering the national public and private stakeholders active in the hydrogen sector to promote the development of green hydrogen projects, and promoted the Smart Grids Innovation Accelerator, a cloud-based online platform to share policy, regulatory, technical, and financial knowledge related to smart grid solutions. In June 2021, Italy joined Mission Innovation members in launching MI Phase 2, by co-leading the Green Powered Future Mission and being member of Clean Hydrogen Mission.

The MiTE strong support the Italian participation into the International Energy Agency (IEA) Technology Collaboration Programme (TCP). The TCPs cover five broad technology areas: end-use technologies; renewables and hydrogen; fossil fuels; fusion energy; and cross-cutting issues such as modelling and gender parity. Italy, thanks to its specialised bodies, plays a very active role, taking part directly in 22 out of 38 of them (indirectly, through EURATOM, in 8 related to fusion power). Particular attention is devoted by our country to renewables and hydrogen, sectors in which we are present in almost all 9 TCPs. In this respect, Italy has supported the SolarPACES TCP since its creation and still has a strong representation from the scientific community.

2.3.2 Overview of the context for industry

The desk research and the preliminary interviews helped ESTELA refine its understanding of the energy context in Italy. The following subsections were enriched thanks to ESTELA's own desk research and inputs from the following stakeholders: The ENEA, the Italian TSO (TERNA S.p.A.), and the private company ENI S.p.A. have been particularly helpful, facilitating the contacts and providing us with a thorough context of energy policy and interests in Italy.

2.3.2.1 Energy policies and political strategies in the Italian landscape

The following section presents the current energy mix in Italy as a basis for the Italian NECP from 2019 that represent together the core features of the Italian energy policy strategy. However, at the time of writing, new considerations popped-up across Italian authorities that should lead to substantial adjustments of the initial strategy.

2.3.2.1.1 Current energy mix in Italy

Italy's energy system heavily relies on fossil fuels, which are mostly imported. In 2020, natural gas and oil accounted for 42% and 32% of total energy supply (TES), respectively. On average between 2016 and 2020, Italy imported more than three-quarters of its TES. Renewable energy sources accounted for 71% of domestic energy production, about 20% of TES and 40% of electricity generation in 2020. Natural gas dominates the Italian electricity mix, covering nearly half of total electricity generation. Italy has a strong dependency on Russian gas, which accounted for 43% of its total gas imports in 2020; Russian oil imports accounted for 14% of oil net imports, third after Azerbaijan and Iraq.

The government has recently expressed a determination to cease importing gas from Russia by 2025.

Italy's energy demand was fairly stable over the last six years, with the exception of the pandemic year of 2020. The Covid-19 pandemic led to a 7.7% drop in TES in 2020 from the previous year. Oil (mostly used in transport) and natural gas (used in buildings and industry) together covered two-thirds of total final energy consumption (TFC) in 2020. In the same year, buildings were the main energy user (42% of TFC), followed by industry (31%) and transport (27%).

Italy is highly dependent on fossil fuels, i.e., oil, petroleum products and natural gas, which altogether represent 62% of the total final energy consumption in 2020, as shown in Figure 10[40]. Table 7 shows that households is the sector with the highest share (i.e., 29,7%) in the final energy consumption of Italy, followed by transport (i.e., 28,1%) and industry (i.e., 23,2%). Figure 11 presents in detail the breakdown of energy sources used by sector.

Sector	Final energy consumption ktoe	Final energy consumption %
Industry	23861,1	23,2%
Transport	28976,5	28,1%
Commercial & public services	16557,6	16,1%
Households	30656,0	29,7%
Agriculture & forestry	2758,9	2,7%
Fishing	202,3	0,2%
Other	44,9	0,0%
Total	103.057,1	100,0%

Table 7: Breakdown of final energy consumption by sector in Italy, 2020 (Source: MiTE)

[40] *Source: MiTE, available at: https://dgsaie.mise.gov.it/bilancio-energetico-nazionale*

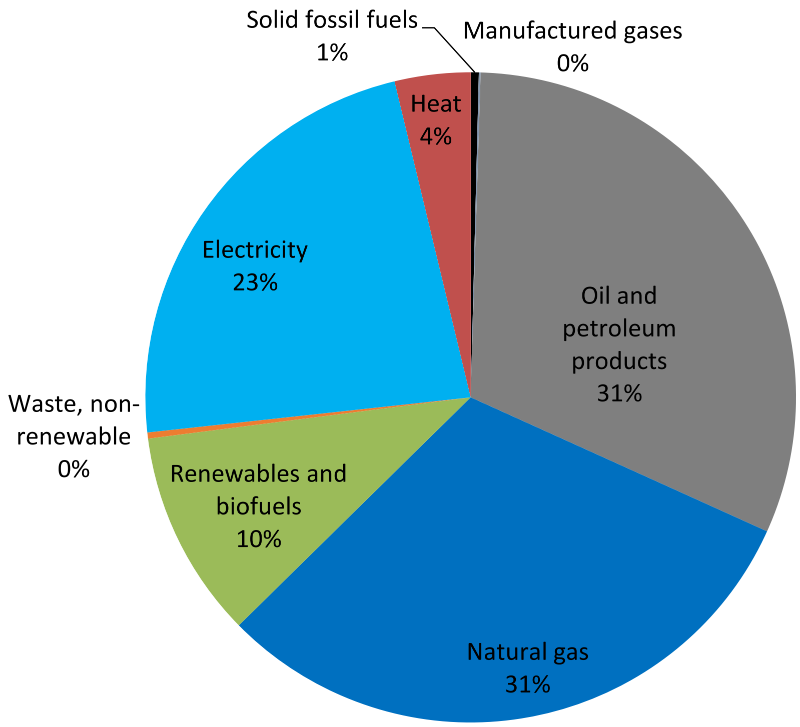

Figure 10: Percentage breakdown of final energy consumption by fuel in Italy, 2020 (Source: MiTE)

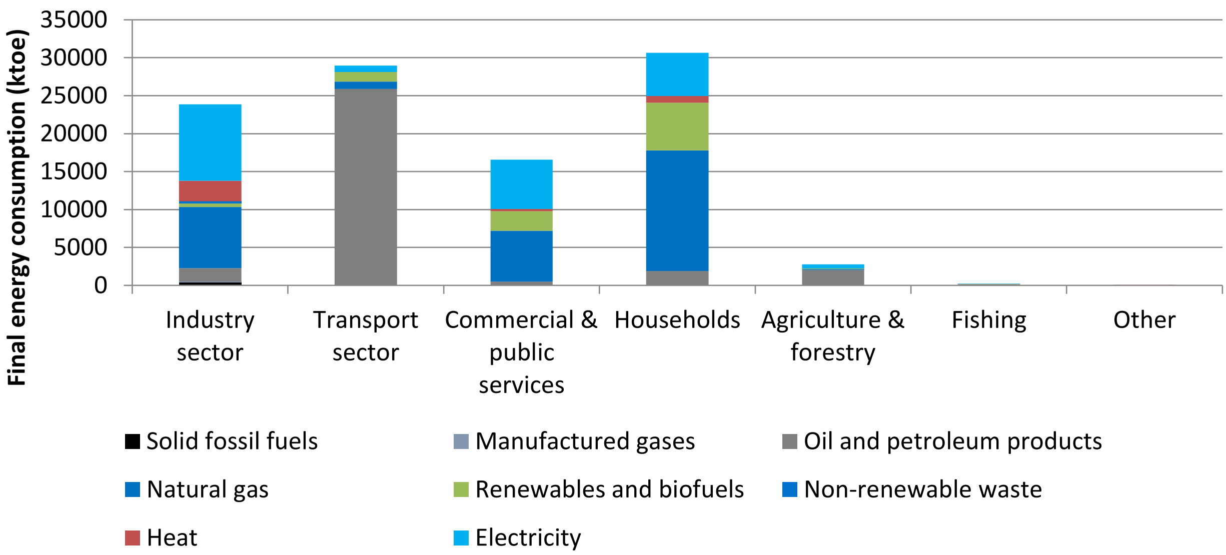

Figure 11: Breakdown of energy sources in final consumption by sector in Italy, 2020 (Source: MiTE)

In the three most energy-consuming sectors (Figure 12), natural gas represents more than half of final energy consumption in households, oil and petroleum products are dominantly consumed in the transport sector, while electricity and natural gas account for more than three-quarters of the energy consumption in industry. Importantly, almost one-fifth of energy consumption in households stems from renewables and biofuels, while heat consumption is 11,3% of the final energy consumption in the industry sector.

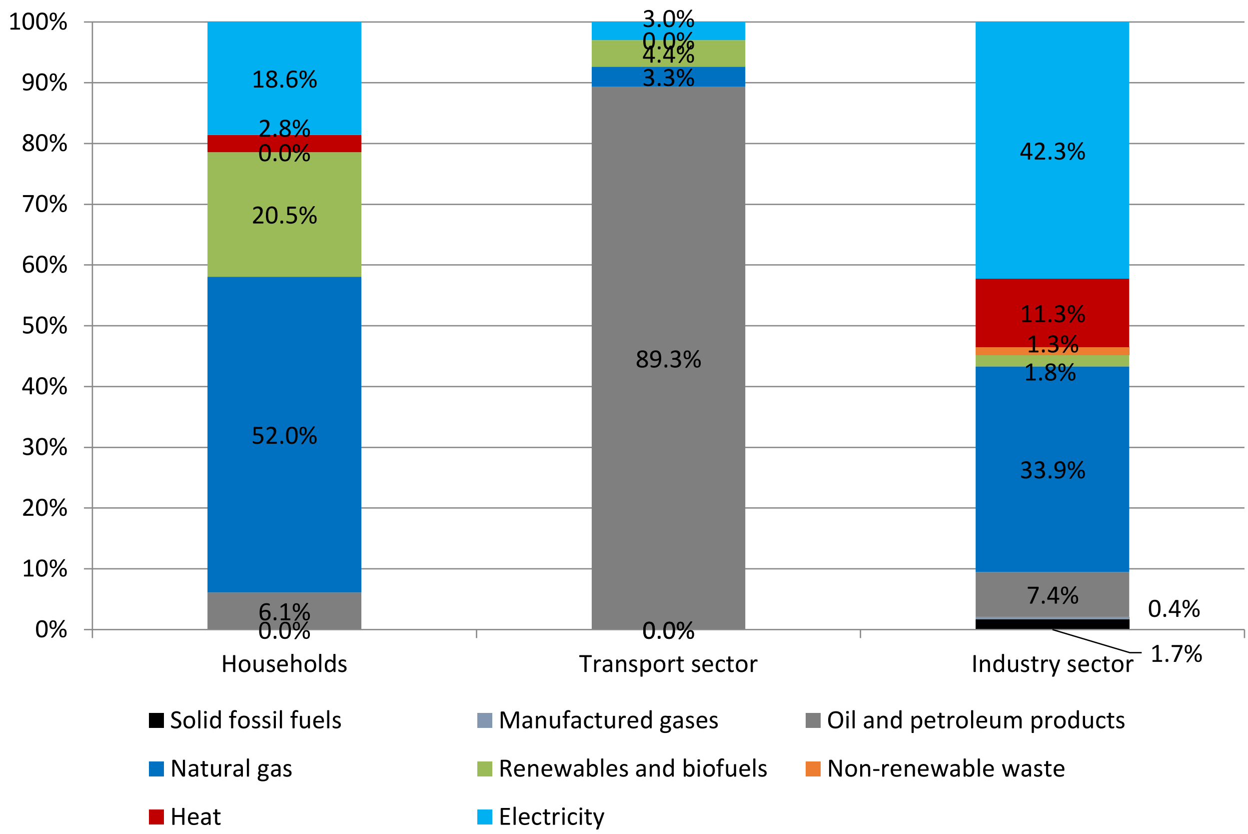

Figure 12: Share of energy sources in three main consuming sectors

In 2020, fossil fuels represented 56% of electricity generation in Italy, as shown in Figure 13. Renewables account for 43% of total electricity generation, with hydro having the highest RES share (equal to 18%), followed by solar, combustible renewables and wind.

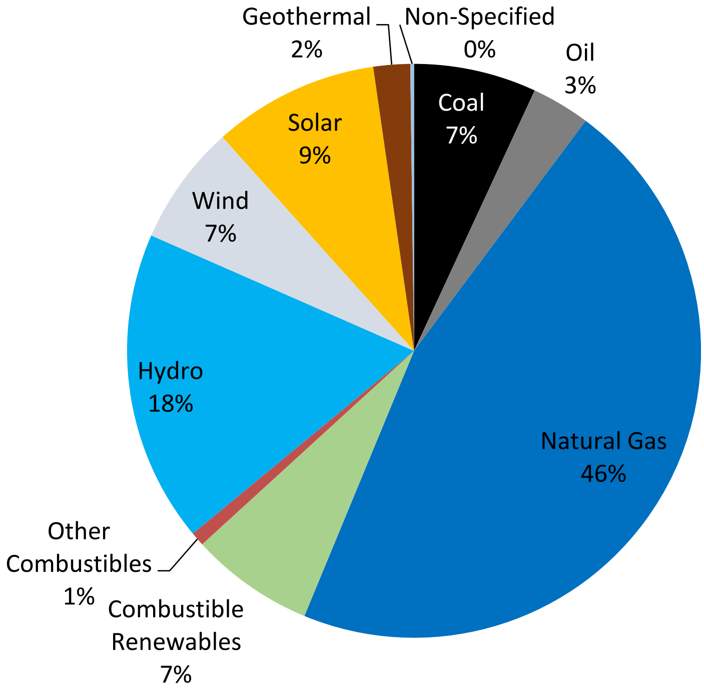

Figure 13: Electricity generation by source in Italy, 2020 (source: IEA)

Italy's share of renewables in total final energy consumption (TFEC) grew from 12.8% in 2010 to 17% in 2014, driven by an exponential growth of solar photovoltaics (PV) and a sustained growth of wind. Renewable energy production has remained relatively stable at about 750-800 PJ since. Its share in TFEC also hovered around 17% until 2019. It jumped to 20.4% in 2020 due to the dramatic fall in energy consumption resulting from the Covid-19 pandemic. This allowed Italy to overshoot its overall and sectoral renewable 2020 targets, as set out in the 2009 EU Renewables Directive. Bioenergy, mainly direct use of solid biomass, remains the main renewable source, covering 55% of total renewable energy consumption. Hydro follows with 21%.

Under the 2018 EU Renewable Directive, Italy aims to reach by 2030 a share of 30% renewables in gross final energy consumption, 55% in electricity, 34% in heating and cooling and 22% in transport. The government estimates that renewables should grow to 65% of electricity generation to be in line with the EU Fit-for-55 package. The Long-Term Strategy (LTS) envisages that renewables should reach 85-90% of gross final energy consumption by 2050 to achieve carbon neutrality.

The government considers the accelerated implementation of renewable electricity, biomethane, biofuels and green hydrogen projects as a cornerstone towards decarbonisation and reducing the dependency of fossil energy sources. Renewables in all sectors have long benefitted from a variety of support schemes. In addition, the NRRP allocates about EUR 6.5 billion to several renewables-related projects, including for energy communities, biomethane, offshore renewable plants, and hydrogen. However, implementation has focused on the transport and power sectors. Less attention has been paid to the use of renewables for heating and cooling. Better targeted support measures are needed to encourage renewables uptake in this sector as well. The complexity of permitting procedures, the variety and instability of support schemes, and local opposition have held back the growth of renewables since 2014. There is an urgent need to address these obstacles to accelerate the deployment of renewables as planned.

Electricity generation from renewables grew to cover 38% of gross final consumption of electricity in 2020, well above the target of 26.4%. Hydropower has traditionally been the main source of renewable electricity generation in Italy, covering 40% of renewable electricity generation in 2020, followed by solar (21%) and wind (16%). Electricity from PV experienced an impressive growth in the early 2010s. However, the growth rate has strongly declined since a generous feed-in tariff ("conto energia") was discontinued in 2013. There is a considerable disparity in renewable electricity generation across regions, with most actual and potential generation from variable renewable sources (solar and wind power) in the southern regions. However, most electricity demand is in the northern regions of Italy. A massive development of renewable electricity capacity in the South, with its favourable geographical conditions for wind and photovoltaics, should be accompanied by investment in the grid and storage capacity as well as encouraging consumers to become an active part of the energy market as "prosumers" to avoid curtailment of renewables. The government states that renewable capacity should increase by 60/70 GW until 2030, at an annual rate more than six times higher than that seen since 2014. Achieving such higher growth rates requires effective streamlining of permitting processes for the renewables plants and the transmission grid. The even higher number of renewable energy sources (RES) projects applying for grid connection (168 GW) seems to indicate that there is additional untapped potential for RES electricity production in Italy.

Italy has adopted different instruments to support the deployment of electricity from renewable energy sources, including support for energy production, grant aid, quota obligations and fiscal incentives. Feed-in tariff (FiT) and feed-in premium (FiP) schemes have been the main support instruments. Several such schemes coexist. The type and amount of FiT and FiP support vary with technology, capacity and age of the plant. There are different channels to access the incentives, depending on the incentive scheme, including auctions and direct access. In addition, renewable power plants and combined heat and power (CHP) plants up 500 kW can benefit from net billing or net metering ("scambio sul posto"). They receive a payment based net injections of electricity in a given calendar year. This system has facilitated the deployment of small-scale PV plants after the end of the PV-dedicated FiT ("conto energia") in 2013.

Since 2017, Italy has also provided incentives to produce electricity, heating and cooling from locally available renewable sources in the 20 Italian small islands without a connection to the national grid. In 2020, the government introduced a FiP scheme for energy communities and collective self-consumption, defined as final consumers/renewables producers that group together to share electricity locally produced by new renewables plants with a capacity up to 200 kW.

To ensure stability and efficiency in future support schemes, a long-term schedule for five years and more competitiveness will be implemented in order to give investors a better idea about policy objectives. This should also encourage and enable new competitors to enter the market and encourage existing companies to ramp up their capacities in a timely manner.

To further stimulate the growth in renewable electricity generation, the government plans to extend the use of competitive procedures and purchasing power agreements for large plants; prioritise photovoltaics on buildings or areas not suitable for other uses; promoting self-consumption and energy communities; preserve and optimise existing production (e.g., revamping and repowering existing plants); and ad hoc support schemes for innovative technologies with cost reduction potential.

In 2021, the total installed capacity for electricity production in Italy was 116.3 GW, with the percentage breakdown by source shown in Figure 14. Hydro and PV account for the largest share of installed RES, which combined represent 38% of total installed capacity. Figure 15 shows the energy balance of Italy by source in 2019, 2020 and 2021, representing a total of 319.677,6 GWh, 301.293,1 GWh and 318.096,2 GWh respectively. Even though Figure 15 shows a small percentage decrease of thermal technologies over the three years, their contribution in absolute terms increased by 6650,3 GWh in 2021 compared to 2020. Similarly, the PV contribution increased by 1.646 GWh, while the international electricity exchanges increased by 10.586,1 GWh.

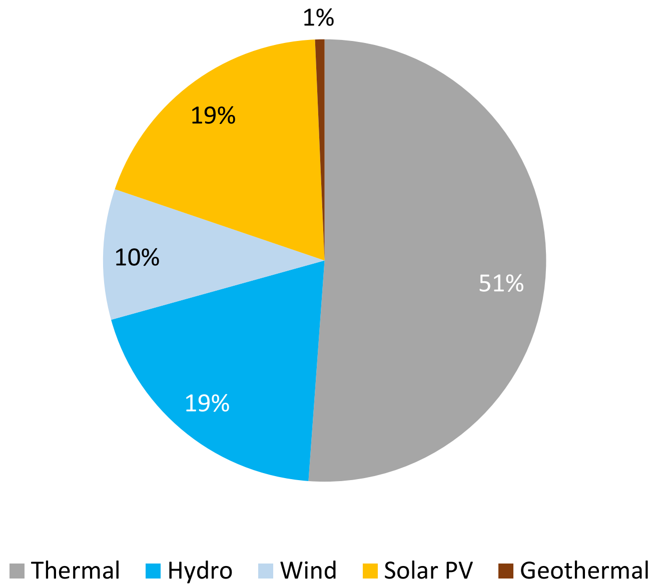

Figure 14: Percentage breakdown of installed capacity for electricity production by source in Italy, 2021 (source: TERNA)

As of 2021, the installed RES capacity in Italy was 56,8 GW, with the distribution of each technology as shown in Figure 16. Hydro and PV are the dominant RES in the country, each one with an installed capacity almost twice as much as wind.

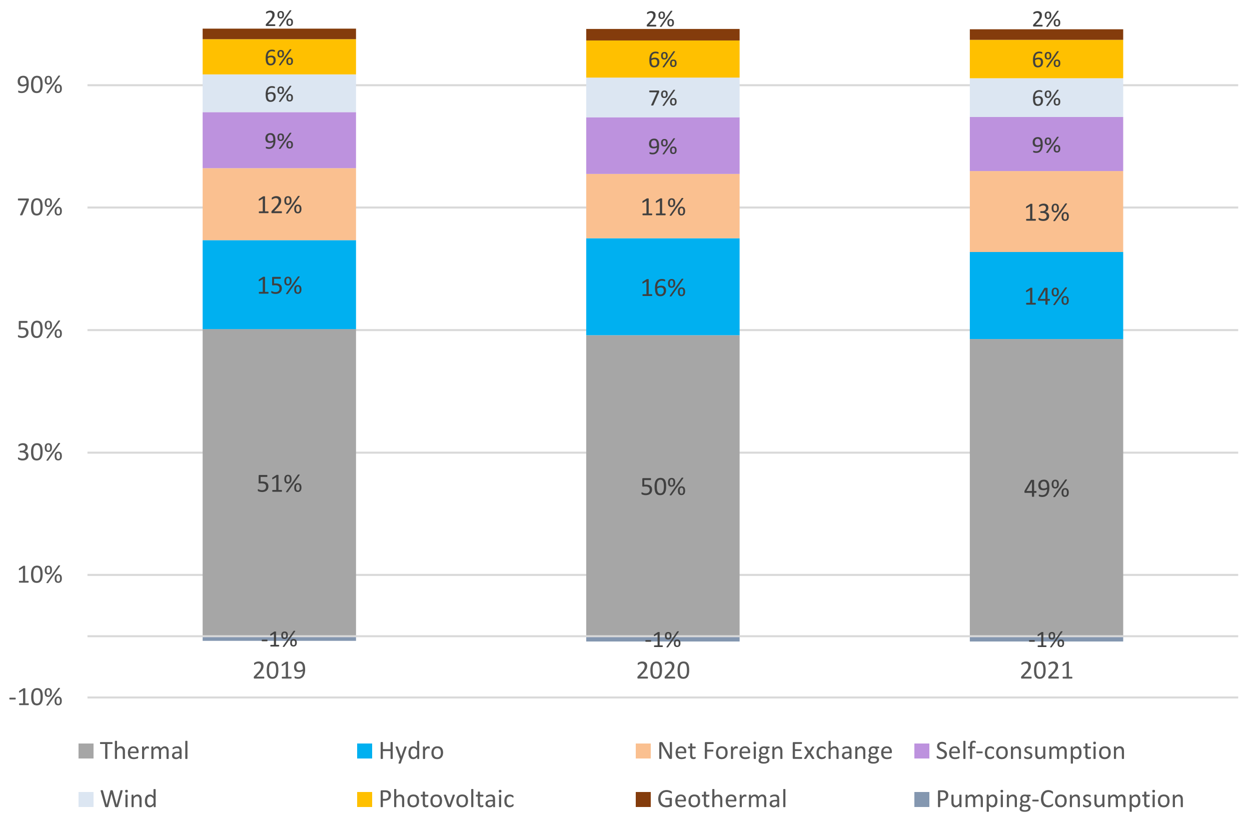

Figure 15: Energy balance of Italy from 2019 to 2021 (source: TERNA)

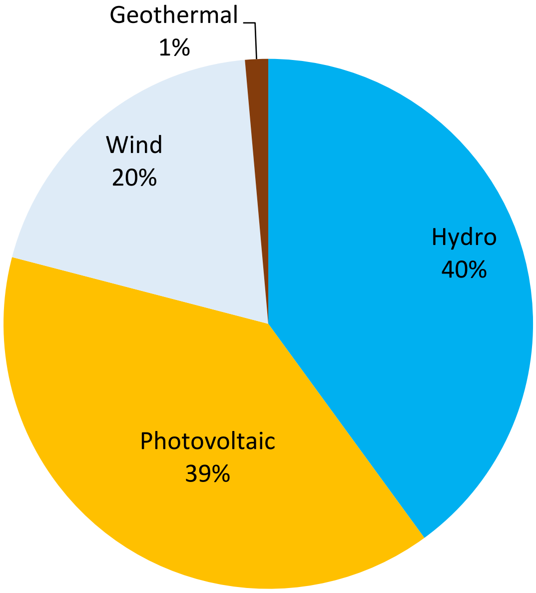

Figure 16: Percentage breakdown of installed RES capacity for electricity production by source in Italy, 2021 (source: TERNA)

Figure 17 depicts the monthly breakdown of electricity production by source from January 2019 to March 2021 in Italy, clearly showing that the high dependence on natural gas power plants.

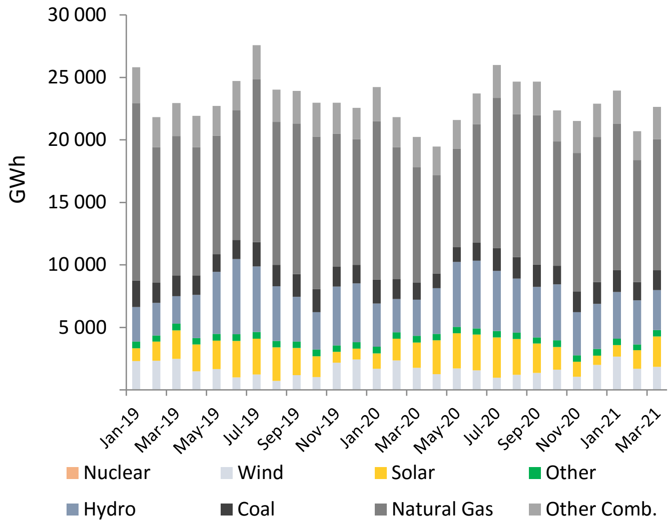

Figure 17: Monthly electricity production in Italy (source: IEA)

The Italian electricity transmission system includes interconnections with France, Switzerland, Austria, Slovenia, Montenegro and Greece. The interconnections balance in 2020 (Table 8) shows that Italy was a net importer of electricity, with significantly higher quantities of imported electricity compared to those exported.

Interconnections balance in 2020	
Electricity imports [GWh]	39.786,9
Electricity exports [GWh]	7.586,6
Net imports [GWh]	32.200,3

Table 8: Electricity imports and exports in Italy, 2020 (source: IEA)

2.3.2.1.2 Important features in the Italian NECP

2.3.2.1.2.1 Potential of CSP and current CSP projects

Italy has submitted an ambitious NECP, with a greenhouse gas emission reduction target of 37% by 2030, whose resultant is energy efficiency, with an estimated reduction of primary energy consumption of 43% and final energy of 39.7%,

Italy is one of the countries that are most committed to pursuing the objectives that aim to environment protection, energy security, and the reduction of polluting and climate-changing emissions laid down by the EU. The NECP for the period 2021-2030 also deals with emissions, and the target is a 33% reduction in greenhouse gases for the covered sectors.

In terms of renewable energy, emissions and energy efficiency Italy aims to reach the following targets for 2030:

- 30% of renewables in the gross final energy consumption.

- 55% of renewables in the electricity sector.
- 22% of renewables in the transport sector.
- 33.9% of renewables in the heating sector.

To reach these objectives, Italy foresees an expansion of the RES installed capacity by 2030 as shown in Table 9. Importantly, its NECP considers that CSP is introduced in the electricity system with an initial capacity of 250 MW by 2025 which shall be increased to 880 MW by 2030.

Source	2016	2017	2025	2030
Hydropower	18,641	18,863	19,140	19,200
Geothermal	815	813	920	950
Wind	9,410	9,766	15,950	19,300
Of which off-shore	0	0	300	900
Bioenergy	4,124	4,135	3,570	3,760
Solar	19,269	19,682	28,550	52,000
Of which CSP	0	0	250	880
Total	52,258	53,259	68,130	95,210

Table 9: Growth targets for power (MW) from renewable sources for 2030 (source: NECP)

Looking forward to 2050, the main objective is to rationalise priorities in order to be able to implement the strategy for renewing the energy targets taking into account the strengths of the national system and the system requirements.

Storage systems and energy efficiency in the industry and buildings sectors are subjects that are well reflected among research entities aiming at demonstrating the considerable potential for industrial projects especially beyond 2025.

In recent years, there has been a strong focus on more extensive use of alternative sources, partly driven by environmental constraints that have provided an impetus for new technological demand.

Besides a first-of-a-kind demo plant (Archimede, 5 MW_e equivalent) based on molten salt parabolic through, built in 2010 and currently non-operational, there are 4 projects at different stage of development:

- Rende plant, in operation since December 2013
- Partanna plant, in the advanced commissioning phase
- Stromboli plant, in the construction phase
- Bilancia plant, in the development phase

Rende is a 15 MWe hybrid CSP-biomass plant (Table 10), located in Rende (Calabria).

Technology	LFR
HTF	Thermal oil (up to 300°C)
TES	No
Capacity	1 MW CST
EPC	Falck Renewables (IT)

Solar field provider	Elianto (IT)
Receiver tubes	Archimede Solar Energy (IT)

Table 10: Rende plant information

The Partanna plant (Figure 1), located in Partanna (Trapani, Sicily), has an installed capacity of 4.26 Mwe (Table 11)[41] and is capable of producing electricity for over 1,400 families (about 30% of the population of the municipal area, with 3 kW domestic users). The expectation is to reach a TES capacity of 180MWht - about 15 hours of operation of the system at full load[42]. It is the first plant built in Italy that integrates CSP with PV.

Figure 18: Aerial view of Partanna plant

Technology	LFR
HTF	Molten salt (290-545°C)
TES	2-tank direct (15 h)
Capacity	4.26 MW
EPC	FATA (Danieli Group, IT)
Solar field provider	FRENELL GmbH (DE)
Receiver tubes	Archimede Solar Energy (IT)

Table 11: Partanna plant information

The Stromboli plant (Figure 19) has an installed capacity of 4.00 MWe (Table 12) and is currently in the construction phase. On 18 February 2020 FATA signed the EPC contract with the "project company" Stromboli Solar S.r.l. for the construction of another CSP plant in Trapani for a total power of 4 MWe. The Stromboli Solar plant collects the experiences and lessons learned accumulated by FATA during the development and construction of the sister plant located in Partanna, now in the process of entering into industrial operation. In Stromboli Solar, FATA also directly supervised the primary reflectors

[41] Luca Turchetti (ENEA), "Is the Italian CSP market nearing a turning point?", 27th SolarPACES Conference, September 27, 2021.

[42] See: https://helioscsp.com/enea-alliance-and-industry-for-two-new-concentrated-solar-power-plants-in-sicily/

production factory, optimizing productivity and unit costs in order to open the way for more competitive and larger plants.

Figure 19: Aerial view of Stromboli plant

Technology	LFR
HTF	Molten salt (290-545°C)
TES	2-tank direct (15 h)
Capacity	4.00 MW
EPC	FATA (Danieli Group, IT)
Solar field provider	SUNCNIM (CNIM Group, FR)
Receiver tubes	Huiyin (CH)

Table 12: Stromboli plant information

Finally, on September 29th, 2021, FATA signed the EPC contract for the construction of the third concentrated solar plant in the municipality of Mezzojuso, in the province of Palermo (Sicily). Of particular importance is the trust placed in FATA by BILANCIA P.V. reputed investors: FONTAVIS AG – member of SWISS LIFE Asset management, together with the Swiss company EBL (Genossenschaft Elektra Baselland) both active in the renewable energy sector. The features of this third plant are similar to the previous ones with particular attention to improve efficiency in energy production. The plant uses, in analogy with the previous plants, a binary mixture of molten salts both as a heat-conveying fluid and as a thermal energy storage with an accumulation capacity equal to 16 hours of continuous operation at full power; the plant occupies a total area of approximately 145,000 m^2 with a mirrored surface of approximately 84,000 m^2.

2.3.2.1.2.2 Hydrogen Strategy

While the system value of CSP was not recognised by the decision-makers and system planners compared to wind and PV, the deployment of batteries or "green" gas and hydrogen remains high on the political agenda.

Hydrogen is in a position to contribute to the national environmental objectives with safer and more renewable energy production, in particular, hydrogen can play a dual role for the country. In the long term (till 2050), hydrogen is hoped to support the decarbonisation efforts - together with other low-carbon technologies - especially in hard-to-abate sectors (such as energy-intensive production processes or energy-intensive production processes or aviation); in the short term, up to 2030, hydrogen will progressively become competitive in applications such as chemicals, chemistry, mobility, oil refining, which would then result in the development of a national hydrogen ecosystem.

As stated in the European Hydrogen Strategy, an appropriate infrastructure will be a key condition for the development of the hydrogen market with the existing gas infrastructure as efficient lever to transport hydrogen. The National Strategy insists on the existence of a well-developed and interconnected gas network that also offers opportunities for import and export.

From 2022 on, efforts will be focusing on two aspects. On the one hand, on the definition of project ideas that take into account both the outcome of the discussions with the network of stakeholders already working in the hydrogen sector as well as hydrogen-related projects that have been discussed with MiSE; these also include R&I issues and on the other hand, on the drafting of policies to support the development of the hydrogen market in Italy.

In this context, MiTE will convene meetings with main stakeholders to further develop specific topics of its strategy. In November 2020, the MiSE published the "Italian Hydrogen Strategy: preliminary guidelines" (the "Hydrogen Strategy"). This document sets a medium and a long-term objective, according to which the national energy consumption is expected to con-sist of 2% hydrogen by 2030 and 20% by 2050. The Hydrogen Strategy also identifies the sectors that will be crucial for the use and development of the hydrogen, such as public transportation, chemicals and refining. Italy-based global utility Enel plans to integrate electrolysers in renewable energy facilities in order to produce and sell green hydrogen to industrial clients, increasing its green hydrogen capacity to over 2 GW in 2030.

The plants will be located near two ENI S.p.A. refineries, where green hydrogen may represent the best decarbonising option. Each of the two pilot projects will include an electrolyser of about 10 MW and it is expected that both will start to generate green hydrogen by 2022-2023.

2.3.2.1.2.3 Biomethane strategy

The hybridisation of biomethane with CSP would facilitate the introduction of CSP technology in the energy market since this will reduce both financial and environmental costs due to gains in terms of energy efficiency and carbon footprint compared to pure gas-fired plants.

More specifically, the ability to hybridise solar energy with other renewable energy resources such as biomethane considerably improves the financial viability of this technological solution, since it allows the production of 100 percent renewable electricity. Gas consumption from renewable energy (biogas, biomethane or syngas) makes possible the use of more efficient, sustainable and competitive combined cycle technologies.

In 2020, 11 new plants went into operation in Italy reaching a total of 27 plants to produce biomethane with overall capacity of 25,445 cubic meters per hour, equal to approximately 220 million cubic meters per annum[43].

Natural gas is perceived as immediate contribution towards environmental sustainability. Even in its fossil form, methane is less impactful than other traditional fuels, as it contributes drastically to the reduction of local pollutants. This impact decreases further due to the use of biomethane, a 100% renewable fuel and locally produced, which is an example of circular economy.

The production and use of biomethane would also help the country to achieve energy independence. In this sense, National Federation of Natural Gas for Distributors and Transporters of Vehicles[44] is advocating towards the government and institutions to tackle the current price crisis with solutions that are effective in the short term.

2.3.2.1.3 Latest energy policy considerations (March 2022)

As in all EU Member States, the energy price peaks that emerged in early 2022 and even more the beginning of the belligerent intrusion of Russia in Ukraine had a disruptive effect on energy policy also in Italy, a country among the most impacted with a 46%-reliance on Russian gas. Besides its effects on the national economy, these events are also seen as able to entail disastrous consequences for the climate and for the European and national green deal objectives achieved so far, until 2022.

Due to recent price increasing of energy and fuels, prices are expected to remain high as long as gas supplies are compromised or insecure.

As primary effect on European governments, efforts are made to secure and mobilise energy reserves that might not have been seen as a priority so far: this stands true for CSP.

More concretely, the Italian government is paying more attention to the NRRP to counteract the impact of high energy prices and reinterpret or consider some basic aspects of the national plan, i.e., the budgeting rules for new projects.

Most of these considerations are directed to the national gas production. For the period 2022-2031 industries will have to raise their reserve to at least one-third for small and medium-sized enterprises, which will imply important moves at diplomatic level to diversify supply.

Since the main obstacle to the deployment of more renewables in Italy was linked to authorisation procedures, unblocking authorisations could be a step forward to achieve the objective of the PNRR of 70 GW of renewables by 2026. It takes up to seven years to complete the authorisation process for a renewable plant. This is incompatible with the urgency of solving this serious crisis.

In 2021, 77% of Italy's energy needs were covered by imported fossil fuels, i.e., gas, oil and coal, while the remaining 23% came from domestic production mainly made up of renewable sources, since only 5% of Italy's fossil fuel needs are produced domestically.

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[43] *See: https://www.assogasmetano.it/biometano-mappa-impianti-italia-e-europa/*

[44] *See: https://www.federmetano.it/*

This is why – under the current conditions more than ever – the potential of renewables in Italy appears in a new light and is globally estimated to around 60 GW in plants that the electricity sector would need over the next 3 years, triggering investments of some 85 billion euros and creating 80,000 new jobs. More efficient authorisation procedures before June 2022 might deter savings of 20% of imported gas.

Among other short-term initiatives appear:

- The "unblocking" of offshore wind power projects.
- While the Italian NECP announces around 1 GW of new wind farms per year by 2030, the EU's new renewable energy target alone – 40% of RES by 2030 – will require Italy to build even more.
- Since the end of 2021, the government has unblocked 18 projects out of which 6 projects by the Council of Ministers in December and 12 projects by the Prime Minister. These projects are: Cerignola Veneta Nord (50.4 MW) and Cerignola Veneta Sud (79.8 MW) wind farms, the "Banzi la Regina" wind farm in Potenza (43.2 MW), the "Lampino" plant in the province of Foggia (79.8 MW) and the wind farm in the municipality of Montemilone in Potenza (for 60 MW)[45].
- The "unblocking" of biogas (biomethane) plants with the aim of reaching 200,000 tonnes in 2023 and an increase of 50,000 tonnes per year in the following three years.
- The relaunch of activities around nuclear fusion, with a first reactor planned by 2028, paving the way for relaunching nuclear power, which however raises also some critics across policy makers and industry leaders.
- Regarding the current regulatory conditions, the MiTE will release by September 2022, a new policy measure for supporting the construction of geothermal, biomass, biogas, thermodynamic solar, and offshore wind power plants, and is part of the measures aimed at targeting the 2030 objectives on Italian renewable sources, called: Fer 2 decree.
- The new features of the decree[46] provide for a five-year planning period to give stability to the measures, given that some technologies have high costs and require long and complex phases for project development.
- To stimulate the progressive reduction of costs, the decree foresees that the small plants to be incentivised will be selected on the basis of environmental protection requirements and at a discount in the basic tariff. Importantly, projects for power plants above 10 MW will receive an accelerated assessment.
- Large plants will be selected based on rankings defined on the rebate and suitability of areas.

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[45] See: https://finanza.repubblica.it/News/2022/03/11/energie_rinnovabili_governo_accelera_con_sblocco_di_18_progetti-23/

[46] See: https://www.edilportale.com/news/2022/03/risparmio-energetico/fer-2-in-arrivo-il-decreto_87745_27.html

- The decree defines, for each technology, the requirements that plants must meet to participate in competitive procedures and access the incentives.

2.3.2.1.4 Industry stakeholders

In Italy, the complete value chain of CST technology is relevant and covered by several stakeholders as shown in Table 13. It includes project research development, engineering, procurement, construction, maintenance, and services.

Company name	Company website	Company expertise
Laterizi Gambettola s.r.l. (Soltigua)	www.soltigua.com	Solar collectors (LFR and PT)
CSP-F	www.cspfsolar.it	Solar collectors (LFR)
Elianto s.r.l.	www.eliantocsp.it	Solar collectors (LFR)
Trivelli Energia s.r.l.	www.seagroupe.com	Solar collectors (micro-PT)
Reflex S.p.A.	www.reflexsolare.com	Solar collector mirrors
Almeco S.p.A.	www.almecogroup.com	Solar reflectors
IDEA SOC. COOP.	https://www.idea-on-line.it/	Sun tracking systems
SAES Getters S.p.A.	www.saesgetters.com	Solar receiver components (getters)
BFR Meccanica Srl	www.bfrmeccanica.it	Solar collector frame and support structures
COMES s.r.l.	www.comes.cc	Solar collector frame and support structures
Meccanotecnica Umbra S.p.A.	www.meccanotecnica.it	Solar collector frame and support structures
Sun Gen S.r.l.	www.sungen.it	Solar collectors (SD)
D.D. s.r.l	www.dd-srl.it	Solar collector support structures and sun tracking systems
Astroflex S.p.A.	www.astroflex.it	Stainless steel flexible hoses
Ansaldo Energia	www.ansaldoenergia.it	Solar steam turbines
Turboden S.p.A.	www.turboden.eu	Solar steam turbines and organic Rankine cycle systems
Exergy S.p.A.	www.exergy-orc.com	Organic Rankine cycle systems
Fumagalli S.p.A.	www.fumagallivalves.com	Valves for the solar power plant
Enel S.p.A.	www.enel.com	Plant developer
ENI S.p.A.	www.eni.com	Plant developer
Magaldi S.p.A.	www.magaldi.com	Plant developer
Sol.In.Par S.r.l.		Plant Owner
Stromboli Solar S.r.l		Plant Owner

Company name	Company website	Company expertise
FATA group	www.fatagroup.it	Engineering, Procurement and Construction
ESE S.r.l.	www.esesrl.com	Engineering consultancy services
TransientGroup	www.transientgroup.com	Engineering consultancy services
KT - Kinetics Technology S.p.A.	www.kt-met.com	Engineering, Procurement, and Construction
NextChem S.p.A.	www.nextchem.it	Project developer, EPC
Brembana&Rolle S.p.A.	www.brembanarolle.com	Project developer, engineering and construction
ACBoilers S.p.A. (formerly Ansaldo Caldaie)	www.acboilers.com/	Solar receiver developer and manufacturer
Nuovo Pignone S.R.L. (Baker Hughes group)	www.bakerhughes.com/baker-hughes-italia	Technology provider; engineering
RINA Consulting S.p.A.	www.rina.org/	Engineering
Walter Tosto S.p.A.	https://www.waltertosto.it/	Component manufacturing
Franco Tosi Meccanica S.p.A.	https://www.francotosimeccanica.it/	Component manufacturing
Eastman Italia S.r.l.	https://www.eastman.com/	Heat transfer fluids for CSP plants

Table 13: Industry stakeholders

2.3.2.2 Energy regulation in Italy

The ARERA carries out regulatory and supervisory activities in the natural gas, water services, sectors of electricity, waste cycle and district heating.

The Italian government released on March 1st, 2022 the new Energy Decree-Law[47], which contains urgent measures for the containment of electricity and natural gas costs, the development of renewable energies, and the relaunch of industrial policies, and with considerations that lead to operating beyond the quarterly horizon in the action against increasing cost for the consumers.

The ARERA underlines that the government action on the high costs still follows a short-term perspective. The Authority advocates also a long-term action that would, for

[47] *https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=2022-03-01&atto.codiceRedazionale=22G00026*

example, modify the procedures governing in Italy the implementation of ETS auctions, so that the impact of supportive measures for renewables is contained.

In the longer term (once the climate objectives set out in the EU's plans are achieved), energy prices should decrease because generating energy from renewable sources - solar, wind, and hydroelectric for example - has intrinsically low operational cost than fossil fuel plants (no fuel costs).

According to the TSO, the phase-out of coal-fired power plants progresses, together with the increase of electricity consumption for the decarbonisation of industry and transport, will imply new specific measures to quickly authorise and build new capacities.

The official text of the Energy Decree approved by the Council of Ministers on March 18th, 2022 and published in the Official Gazette no. 67 of March 21, 2022, provides interventions aimed at containing the increase in energy and fuel prices.

In addition, it includes measures relating to energy prices and support for households and businesses, as well as protection for industrial and service sectors affected by price rises and the energy crisis resulting from the war in Ukraine.

A few of the important points taken from the Energy Decree can be listed:

- GAS TAX CREDIT FOR BUSINESSES as heavy users of natural gas. The credit is equal to 20% of the expense incurred for the purchase of gas, consumed in the second calendar quarter of the year 2022, for energy uses other than thermoelectric uses.
- TRANSFER OF THE CREDIT FOR ENERGY-INTENSIVE BUSINESSES - The rule therefore also provides for these tax credits, the same mechanism of transfer for example of the bonus facades 2022 or Superbonus 110 %.
- INCREASE EXISTING TAX CREDITS
  - Energy-intensive companies from 20% to 25%;
  - Companies with high consumption of natural gas from 15% to 20%.
- SOCIAL BONUS FOR ELECTRICITY AND GAS - For the period between April 1 and December 31, 2022, the value for access to social bonuses for electricity and gas is equal to 12,000 euros. Therefore, the threshold has been raised concerning the limit of just over 8,000 euros foreseen until March 2022.
- AID FOR ENERGY COMPANIES OF STRATEGIC INTEREST - For energy-intensive companies of strategic interest, until December 31, 2022, it will be a Decree of the President of the Council of Ministers to establish which are the plants of national interest managed by energy-intensive companies. Up to 150 million euros will be allocated to projects for the decarbonisation of the steel production cycle at the Taranto steelworks.
- MONITORING IN THE NATURAL GAS MARKET - the MiTE and the ARERA, will receive the contracts already signed or to be signed by the holders of gas supply contracts for the Italian market, which will be monitored and treated in compliance with the confidentiality of sensitive information.

The decree supports the production of electricity from innovative renewable energy plants or those with high generation costs, through the definition of incentives that stimulate these applications to increase their competitiveness and allow them to contribute to the achievement of the decarbonization targets for 2030.

The decree establishes the terms and conditions under which biogas and biomass, thermodynamic solar, geothermal, and off-shore wind power plants that are innovative and have a low impact on the environment and the territory can access incentives. This is the purpose of the draft decree - the RES 2 Ministerial Decree, the incentives also include the possibility of introducing the remuneration thresholds for CSP installation respectively up to 300 kW and from 300 kW to 5 MW.

At this point, it is important to note that the a.m. information is based on the draft announcement of the new decree relevant to the Italian policy, thus it is possible that the final version to be published might be subject to revisions to reflect on the latest changes.

2.3.2.3 The energy transmission system: towards smart sector integration

A basic pillar in the position of the Italian TSO, TERNA S.p.A.[48], consists in identifying network elements that reduce the need for investments in new grid infrastructures for new interconnections, i.e., using industrially mature and economically viable technologies.

It is, therefore, significant to underline Italy's commitment to initiatives for the support and enhancement of the regional energy cooperation for the Mediterranean region, which is developed, on technical and regulatory levels, ascribing to Italy the role of one of the founders of the Mediterranean Association of the National Agencies for Energy Conservation (MEDENER), Mediterranean Energy Observatory (OME), Renewable Energy Solutions for the Mediterranean (RES4MED), Renewable Energy Solutions for Africa (RES4Africa), Mediterranean Transmission System Operators (MED-TSO), and Mediterranean Energy Regulators (MED-REG). Importantly, ENEA has undertaken the role of Secretariat in MEDENER, Terna in MED-TSO and ARERA in MED-REG.

Within this framework, these projects extend their view far beyond the Italian coast, looking closely at cross-border interconnections in the Euro-Mediterranean region and In this perspective, we can describe the developments implemented by set up by the Med-Tso, the association composed of 20 transmission system operators in the Mediterranean region, including the Italian Terna, has worked to create a major, sustainable electricity grid capable of supplying around 500 million users within the Cross-border interconnections in the Euro-Mediterranean region. representing a community whose integration is an unavoidable requirement, allowing the guarantee of a common future, safer and more pleasant for all populations.

These are the goals of the three EU-MED platforms on natural gas, regional energy market (REM) and renewable energy and energy efficiency (REEE), recently set up under the aegis of the Italian Presidency of the Council of the EU and the European Commission.

The plan has started in 2013 with the Mediterranean Project 1 based on a process of multilateral cooperation, and internal developments in the networks of individual countries, which produced the Mediterranean Interconnections Master Plan, but the

[48] *See: https://www.terna.it/en/sustainability/environment/climate-change*

same year was the scene of rapid and sudden evolution caused by structural changes in the international market, which generated a reversal of the scenario through an exchange system aimed at integrating the electricity and energy systems of the two shores of the Mediterranean. whose good results improved, led so far within the followed project: Mediterranean Project 2 (2018-2020).

The planning was therefore developed according to the following time and space frame:

1. 2015-2016 for the countries of the Eastern Mediterranean area (from Egypt to Turkey and between Turkey and Bulgaria-Greece), which is difficult to plan in the medium to long term due to the political transition phase in Syria, Lebanon.
2. 2022 for the Western Mediterranean area, from Libya to Morocco, (Spain, Portugal, France, Greece). Morocco, (Spain, Portugal, France, Italy), which are going through a difficult transition phase towards transition to new balances in their national electricity systems.

The development of infrastructures such as transport, energy and water are the key to a new, inclusive, work-based development path. The development of infrastructures such as transport, energy and water are the key to a new, inclusive, work-based development path, and among these, energy plays an essential role for the very security of Mediterranean countries, without there would be no development.

This is why the implementation of these projects requires a clear and stable political decision beforehand, clear and stable political decision, especially to:

- Carry out some reference Projects, on which to develop operational tools, cost-benefit assessment to provide a concrete contribution to the development of a Mediterranean chain of Projects, coordinated and interdependent in the long term of a Regional Relevant Electricity Network.
- Articulate a conscious, stable and coordinated decision-making process between electricity companies, and governmental and international financial institutions, require specific conditions that will allow progress in market and collaboration studies, training and knowledge sharing, in the dialogue between stakeholders but that will improve a precise political will to collaborate.

ENEA as a founding member of MEDENER - the Mediterranean Association of National Energy Conservation Agencies, held an international conference on the role of these new bodies, their possible spin-offs and synergy opportunities for Italian small and medium-sized enterprises (SMEs).

In both national and international contexts, ENEA planned information campaigns for the public at a large scale, measures for promoting energy efficiency, coordinated and promoted the activities of the Euro-Mediterranean platform on energy efficiency and renewable and regulatory frameworks and market assets able to encourage investments in the sector.

Another strategic line is to assess the possibility of integrating storage, in smart infrastructures, e.g.: parking, public administration's offices, new building – creating a system that combines the provision of charging facilities and the use the energy inside the battery in a bi-directional way. TERNA S.p.A. has investigated quantitative scenarios for pumped storage hydropower as resulting from the morphology of the territory as well as the development of the electrochemical components (able to deliver reactive power and inertia to the grid).

TERNA S.p.A. has carried out research to verify the feasibility of the sodium–sulphur (Na–S) secondary cell installations in the Italian high voltage network. Three installations are located in Southern Italy with a total capacity of 34.8 MW. Their function in the grid is charging and discharging in long intervals so that they have been called "energy-intensive" installations.

At the time of writing, it is expected to see in early 2022 a 2.5 MW/4MWh first of a kind energy storage facility project launched in Sardinia, which would mean a paradigm-shift regarding utility-scale energy storage technology with a first demonstrator for a CO_2 battery. It will be designed to allow for a future storage increase up to 8 MWh and above. The demo plant will use the same parts as the full-scale commercial system of 25 MW and 100 MWh or 200 MWh, effectively proving the market readiness of this technology. This demonstration project is also meant to be operated commercially and generate revenue by operating on the energy and ancillary services markets.

This technology is based on a new process designed and engineered to use only existing and proven equipment. Doing so, the project would not only result technologically and economically viable now also overcome the inherent limitations of lithium-Ion technology. Notably, the CO_2 battery poses no fire risk, uses no rare materials and marries a better performance with a lower capital cost, as compared to Li-Ion. Energy Dome, the owner this technology, just signed an agreement with Ansaldo Energia, which will provide the turnkey EPC, including performance guarantees, based on the Front End Engineering Design (FEED) developed by Energy Dome.

Upon the release of the Hydrogen Strategy by the EC in 2020, the sustainable production of hydrogen has become an investment priority within the NGEU plan. Accordingly, Italy recently set a PNRR, in which €3.2 billion were allocated for the research, testing, production and use of hydrogen.

According to TERNA S.p.A., CSP was not developed on the electricity generation side in Italy since it didn't rank among the priorities of national decision-makers who discarded its system value compared to wind and PV. On the contrary, the deployment of batteries or "green" gas and hydrogen remains high on the political agenda since perceived as a better match to the national economy at large.

On the demand side, having in mind that half of the demand is in the heating and transportation sectors, these sectors could be open to a larger range of applications based on various technologies, among which CSP could emerge.

TERNA S.p.A. has high expectations regarding interconnections as contribution to solve the expected storage needs of the future.

An undersea interconnector between Italy and Montenegro representing an investment of some EUR 1.1 billion was put in operation in 2019. This 445-kilometer interconnector is reported to be important for both the security of the two countries' power systems as well as for the integration of renewables. Upon the completion of the deployment of the cable in 2019, the interconnector enabled Montenegro to become an energy hub for the Balkan countries, while creating conditions to attract other investments, including in RES. The initial capacity of 600 MW will be upgraded to 1,200 MW via the construction of a second interconnection line, which is expected to be commissioned in 2026[49].

Another pivotal programme is the interconnection between Sardinia and Sicily (also interconnected with the peninsula) via the so-called Tyrrhenian Link, which is a double underwater cable 950 kilometres long and with a capacity of 1000 MW. The interconnection link consists of two sections, i.e., from Sicily to Campania (east) and from Sicily to Sardinia (west), and aims to increase electricity exchange capacity, facilitate the development of RES, and improve the reliability of the grid[50].

Last March Terna S.p.A.'s Board of Directors approve the update of the 2021-2025 Industrial Plan "Driving Energy". The key driver in the 2021-2025 Industrial Plan is sustainable investment with total capex of €10 billion, Terna's capital expenditure, 99% of which is classified as sustainable, based on the eligibility criterion introduced by the EU Taxonomy, targets the development of renewable sources, with transmission backbones to transport energy from points of production, increasingly located in Italy's southern regions, to where demand is highest in the north of the Country. This will be made possible by resolving existing issues caused by grid congestion and further development of cross-border interconnections. In this regard, Terna has plans to build new interconnectors with France, Austria, Tunisia, and Greece. These will join the 26 existing cross-border power lines and will enable Italy, thanks to its strategic geographical location, to reinforce its role as a European and Mediterranean electricity transmission hub, becoming a leading player at international level.

2.3.2.4 Social acceptance and access to land

Social acceptance issues have proved to be the most important stumbling block also for CSP projects. The corresponding delays or abandon of projects due to social acceptance may turn to be costly when developers are claiming compensations for the power they cannot sell once the plant is ready to start operations. There are a lot of theoretical studies about the transition to a decarbonised economy, with different outcomes regarding the time needed for the transition of the decarbonisation of the heat sector. Nevertheless, all renewable technologies are called in the transition process and can play a role without exclusion of a single technology.

Social acceptance is intrinsically related to access to land, as the local population contests the right of developers (especially when these are large corporations) to use the land where they live or work. Issues of compensation and consultation are more complex when land users do not hold formal titles. Such a lack of clarity over land rights may lead local communities to seek compensation unused or abandoned.

The geographical and morphological arrangement of the plants create an obstacle that translates in a low social acceptance. The underlying causes for a lack of social acceptance and access to land in Italy are:

- Lack of clarity about land value, land property rights, and the land acquisition process.

[49] *See: https://tyndp.entsoe.eu/tyndp2018/projects/projects/28*

[50] *See: https://www.terna.it/en/projects/public-engagement/Tyrrhenian-link*

- Imbalance between the costs and benefits for local communities (where infrastructure is located), urban residents (getting the service), and investors (profiting from it).
- Lack of consultation with local entities as well as about the process for remuneration of the access to land.
- Interference of local politicians seeking political or financial gain.

As a result, it appears that a higher acceptance should be achieved via mode focused actions explaining how a project matches local challenges and their specific needs. This ability to engage local communities confronting the opinions of all the people and institutions is key for achieving a consensual solution about the siting of new infrastructures and/or its revamping to lower its impact on the environment.

Local entities perceive the hosting of an infrastructure of strategic importance for the country as detrimental to their sustainable development. Such a resistance at local level is one factor blocking the development and implantation of CSP, in particular in big plants. The most frequent arguments invoked are:

- Firstly, environmental hazards on land (for example referring to flammable liquids or alleged risk of leakage of heat transfer fluids).
- Secondly, the difficulty of obtaining all administrative permits from local authorities for the construction of plants (including pilot plants). This difficulty with the permitting process stems from the slowness of administrative procedures at the level of regional institutions that conflict with national regulations and the relevant European directives.

There are ongoing feasibility studies for CSP installation:

- In the Agri Valley (Basilicata), a project that would have a positive impact due to the creation of new jobs was dropped since the perceived dangers and their negative impact on the landscape prevailed.
- Another example is ENI S.p.A. (one of the major industry stakeholders mentioned in Table 13) expects a substantial development of CSP in Italy and especially Southern Italy is in contact with actors involved in research, development and with ENEA. An example of projects considered is a chemical facility for recycling plastics energized by CSP.

In the course of these investigations, a fundamental consideration for the potential use of CSP technology remains the integration with certain technologies already existing in a given area/region (sometimes labelled “non-exclusive” approach to technology or “technology agnosticism”). Nevertheless, some experimental small plants already exist and have obviously overcome the social resistance:

- One is located in Gela – Sicily, connected to oil and gas facilities. A second plant is planned for the near future. The most important aspect of the design of these installations is that they are designed for various uses, such as heating and/or supplying electricity to buildings, with or without thermal storage (the heat emitted by the heat transfer fluid can be used in particular to improve hydrocarbon recovery).

- The region of Sardinia authorised the construction and installation of solar PV plant in Porto Torres (Table 14) situated on the north-west part of the Sardinian coast, a city divided in two parts practically equal in size. One part is the city itself, the industrial area. The other part is since 1997 a national park where ENI S.p.A. provides so called “environmental remediation projects”. In accordance with the local institutions an agreement is sought about measures impacting energy efficiency and environmental sustainability. Even if this new solar PV plant project is on hold until the permitting procedure is closed, the construction is likely to start in 2023 and expected to enter into commercial operation in 2024.

Project type	Total Capacity (MW)	Active Capacity (MW)	Pipeline Capacity (MW)	Project Status	Project Location	Project Developer
Solar PV	42.13	-	42.13	Permitting	Sardinia, Italy	-

Table 14: Status of solar PV plant in Porto Torres, Sardinia

- In June 2019, the Danish company European Energy made an investment in Puglia by acquiring the existing large photovoltaic park in Troia (with a total capacity of 103 MW, 1,500,000 sq. meters) which is the 17th in Europe in terms of size and power.
- In 2020, the Swedish company Mid-summer, chose the industrial area of Modugno (Bari) for the new industrial settlement that will produce flexible photovoltaic modules. For this project, the company has planned an investment of 60 million euros and creating 200 jobs including clerks, technicians and workers[51].

[51] *See: https://press.regione.puglia.it/-/la-societ%C3%A0-svedese-midsummer-investe-in-puglia.-approvato-dalla-giunta-l-accordo-di-sviluppo*

2.4 Key findings

2.4.1 R&I

2.4.1.1 Italy has a strong R&I support programme

Due to its mission: "ENEA is the National Agency for New Technologies, Energy and Sustainable Economic Development, a public body aimed at research, technological innovation and the provision of advanced services to enterprises, public administration and citizens in the sectors of energy, the environment and sustainable economic development (article 4, Law no. 22 of 28 December 2015)". Being also the National Agency for Energy Efficiency, which offers technical and scientific support to companies, supports the public administration in the preparation, implementation, and control of national energy policies, and promotes training and information campaigns for the dissemination of energy efficiency culture. Being the only public research body devoted to energy managed by the MiTE, ENEA is ideally positioned to establish an efficient link between research, industry, and national energy policy. Indeed, the Agency is the coordinator of the Energy National Technology Cluster and is supporting several Regions (last to mention Lazio, Lombardy, Sicily, Apulia) to design their Energy-Climate Regional Plan.

As another specific result, the funding of R&I activities is increasingly aligned with the priorities identified with the SET plan Key Actions, which also encompass solar thermal technologies.

There is a wide spectrum of R&I activities born by highly qualified personnel, advanced laboratories, experimental facilities and excellent instruments for the realisation of projects, studies, tests, assessments, analyses and training services, with particular reference to product and process innovation and the valorisation of results to contribute to the development and competitiveness of the national economic system, currently with a priority on heat applications.

International cooperation occurs besides the other European R&I partners in HORIZON-STE with numerous national and international research bodies and institutions like Texas Tech University, Stanford Research Institute, New Delhi University, the Chinese Academy of Sciences, ICTP, TWAS, and participates in technological platforms and networks like EERA, ECRA (European Climate Research Alliance), MEDENER, and Enterprise Europe Network, the largest network of services supporting competitiveness and innovation for SMEs.

The government is increasing its policy focus on energy-related research, development and demonstration to support the energy transition. Italy's public budget for energy-related RD&D increased from 2016 to 2019 to EUR 509 million or 0.026% of GDP, and private spending in energy R&I was more than double the public budget. Thus, Italy reached its 2020 target of overall RD&D spending equalling 1.5% of GDP. The NECP reiterates the country's commitment under the multilateral initiative Mission Innovation (MI) to double the public funds for research in clean energy, from EUR 222 million in 2013 to EUR 444 million by 2021. RD&D investments are expected to focus on efficiency, biofuels, renewables, advanced materials, hydrogen, and smart grids. Public funds for energy-related RD&D will substantially increase in the coming years, almost EUR 765 million are foreseen. These additional funds have to be absorbed by national projects/activities in a short timeframe, while it is not clear what the funding situation will be after 2026, when these funds end. Additional funding after 2026 would be needed to maintain momentum.

2.4.2 Industry

2.4.2.1 Italy is primarily looking into sector integration

Even if the south of Italy has excellent natural resources for the deployment of RES technologies in general and of CST in particular, Italy is pursuing the objective of sector integration between its electricity and gas assets with an increasing number of new capacities in PV.

The reason why CSP is not developed in Italy is that this technology was not prioritised by decision-makers and system planners focusing on least cost expansion models disregarding the system-value of CSP compared to wind and photovoltaics shifting the costs of intermittence to the system, i.e. relying on gas-fired plants.

The key aspect is the recognition that solar thermal technologies are not competing but complementing PV infrastructures and that this complementarity has a decisive role in periods of changing solar conditions. These can be mitigated by specific operational patters of PV and CSP (PV delivering power to the grid during the day while CSP is charging the storage tanks).

This explains the focus on 'green' gas and hydrogen as well as on batteries in the political agenda – so far. Italian policy makers need to coordinate approaches to CSP to define its value in terms of its contribution to flexibility and for wider uses (heat, fuel).

Bearing in mind that half of the Italian demand is for heat and transport, these sectors should be open to a wider range of applications based on various RES technologies, among which CST can play an important role. But CST-based applications for industry heat and new fuels are becoming active field of research.

2.4.2.2 The key challenge of storage and a potential for extended uses of CST

Well aware of the fact that storage is or will soon become an essential challenge to power system operation, TERNA S.p.A. did not yet considered CSP as a primary solution alleging the lack of urgency and the improvable cost competitiveness of the technology.

Instead, TERNA S.p.A. has extensively investigated quantitative scenarios for pumped storage hydropower as resulting from the morphology of the territory that would be able to deliver reactive power and inertia to the grid.

TERNA S.p.A. is also assessing the possibility of integrating storage in smart infrastructures, e.g.: parking, public administration’s offices, new buildings which would combine the provision of charging facilities and the use the energy inside the battery in a bi-directional way.

TERNA S.p.A. investigated the feasibility of sodium–sulphur (Na–S) secondary cell installations. Three such installations are located in Southern Italy with a total power of 34.8 MW. Their function in the grid is to have charging/discharging cycles in long intervals

1. The plant, with a size of 2.5MWe and 4MWh, will be designed allowing for future storage expansion bringing it to 8MWh and above. The Demo Plant will use the same parts as the full-scale commercial system of 25MW and 100MWh or 200MWh, effectively proving the readiness of this technology for the market.

This demonstration project is meant to be operated commercially and generate revenue by operating on the energy and ancillary services markets. It will deploy the Demonstration Plant, by pioneering an innovative alternative to batteries for utility-scale energy storage.

2.4.2.3 New incentives to renewable solar heat installations

While no specific incentives for CSP exist, e.g. via dedicated auctions for new capacities in the Italian system, some new types of incentives to promote renewable solar heat appear promising. As the NECP shows, the Italian government promotes the development of infrastructures and buildings. In this context, an important incentive is the combined effect since May 2020 of "*Superbonus 110%*" and "*Conto Termico*"[52]:

On the one hand, the *Superbonus 110%* aims to make homes more efficient and safer and provides tax credit to the company realising the renovation measures.

On the other hand, the national "*Conto Termico*" incentivises solar heat plants with sizes up to 2,500 m^2, for several different applications and technologies and with a maximum amount of 65% of the investment cost.

The PNRR is expected to further foster growth by the introduction of additional funding mechanisms and is expected to stimulate other market segments. For the time being, only a third of the available budget has been spent. Already today, a strong increase in grants allocated annually between 2016 (EUR 36 million) and 2021 (EUR 327 million) is reported while the proportion of the available budget used went up from 4% in 2016 to 36% in 2021.

2.4.3 Integrated findings

2.4.3.1 About the absence of CSP in the electricity system

- As all EU TSOs are responsible only for the reliability (operational security and adequacy of the system), the Italian TSO remains technology agnostic and is not active in promoting a higher penetration of RES in the system and even less in promoting a better balanced ratio between intermittent and dispatchable RES. Together with the underlying "classical" capacity remuneration scheme in place in Italy, this leads to a pure least cost system extension philosophy (with a strong focus on interconnections to neighbouring countries along the motto "cheaper than cable") leaving aside any considerations related to the decarbonisation of the power system and shifting the redispatch costs of intermittent sources to the system; incidentally, this also ensures the continuity of business for (recent) combined cycle gas turbines, perceived as "system integration".

[52] *See: https://solarthermalworld.org/news/superbonus-has-pushed-solar-heat-in-italy/*

2.4.3.2 Importance of SMEs

- There are in Italy large corporations but also numerous SMEs with high technological standards involved along the value chain of CSP. These well recognised entities are active on world markets and in the framework of international industry initiatives and projects. Within this wide industrial potential, the above mentioned SMEs showed a remarkable resilience under dire business conditions over the last 2 years, which demonstrates that the deployment of CSP/T could be strongly supported by this type of companies.

2.4.3.3 Permitting process is slow due to bureaucratic shortcomings

- An important challenge faced for achieving a swifter deployment of CSP – but also for most of other technologies linked to larger infrastructures – is the permitting process, perceived by industry as long, burdensome and too fragmented. Special permits are required for pretty much everything. As an example, a company must apply for a permit from the heritage commission if its infrastructure is within 100m distance from a listed building even if the building is not listed as national heritage. Sometimes the permitting process must go through several authorities (national heritage commission and municipal authorisation). In most regions/cities, applications cannot be submitted electronically.

2.4.3.4 Local content of CSP plants instrumental to reduce social resistance especially in stressed rural areas

- The Italian industry would be able to drive a redeployment of CSP in the country. But beyond the positive business impact at national and international level, the "local" content of the CSP technology extends to less known aspects that should be well received in some rural areas or economically stressed regions: the local tax income favouring the local development as well as some in-kind products for rural activities, e.g., the molten salts used in storage tanks of CSP plants can be offered as fertilizers.

2.4.3.5 An overall promising outlook on the Italian NECP objectives

- Globally, the previously described interaction between R&I, industry and authorities is set to increase the overall contribution of renewable sources to the national energy system. Doing so, the objectives of the NECP appear realistic besides the positive business impact on the Italian industry.

2.5 Aligned conclusions and recommendations

2.5.1 Opening doors to redeploy CSP in Italy

- Most importantly, the adjustment of procurement mechanisms (auction features and adjudication criteria) would enable a real valorisation of the system benefits of CST plants for the electricity system – this stands true also for smaller units, especially under the current gas crisis.

2.5.2 Communication about CSP costs

- Substantial cost reductions for CSP plants are expected to materialise just due to "economies of scale" and manufacturing standardisation in case of a CSP European project pipeline. Despite this, the current higher cost thresholds that might be defined for CSP energy in Italy in smaller or medium size plants (approx. 300-240 €cts/kWh) should not be promoted of a "out-of-the-market" recognition of the higher investment costs for a "less deployed technology" but as its true value for the flexibility it adds to the system.

2.5.3 Harmonisation of permitting

- A better coordination for permitting procedures between the national, regional and municipal levels would substantially support the deployment of CST installations but also for any other RES infrastructures: Besides unavoidable political considerations regarding the distribution of competences at local level, the lack of coordination is frequently due to rather simple connectivity issues for bureaucratic tasks. In 2021, the government merged responsibilities over energy, climate, and environment into the newly established Ministry of Ecological Transition (MiTE). Furthermore, a new inter-ministerial committee aims to ensure co-ordination of national policies for ecological transition. Hopefully, this could pave the way to a faster and inclusive permitting procedure. The effects of these policy changes should be monitored closely, to ensure the anticipated speeding up of the realisation of RES projects takes effect in every region of Italy and additional simplification measures should be taken, if needed.

2.5.4 Focus on innovative smaller size plants

- Taking on board the geographical limitation regarding available large sites coupled with the lack of social acceptance for any major infrastructure projects, the initial investments in CSP (supported by efficiently designed, CSP focused auctions) should go to projects with a balanced ratio between environmental sustainability and technical/economical yield.
- Exemplary in this context is the WinWind projects in Tula (Sardinia): To mitigate local concerns, the community was included in a consultation process, resulting in a reduction in the number and density of turbines, and in their repositioning. ENEL also committed to the creation of recreational spaces for hiking, sports or cultural events. To allow the municipality and individuals to share the financial benefit, 2% of the gross revenue of the farm is now given to Tula municipality. The municipality

also consulted its citizens to decide how this income from the farm would be used to benefit the community. This resulted in municipal tax reductions for 1600 households, including the elimination of the personal income and real estate taxes.

- This example shows that including the local communities in the decision-making process and sharing financial benefits lead to an increase in acceptance. However, the possibility to repeat such an experience depends on:
    - clearly identified interlocutor to industry such as the region and/or the municipalities, and
    - the size of the municipality involved. Such a consultation is more difficult in larger municipalities.

2.5.5 Higher visibility of the CST industry at national level

- As mentioned above, the industry texture in Italy that can be involved in CST deployment spans from major companies to numerous know-how holding SMEs. These companies should soon federate and actively demonstrate both the macroeconomic and the regional impact as well as that this deployment would be preventing takeovers of Italian companies by non-EU competitors at no cost.

2.6 Glossary

ARERA	Italian Regulatory Authority for Energy, Networks and Environment
CETP	Clean Energy Transition Partnership
CHP	Combined heat and Power
CIPESS	Inter-Ministry Committee for Economic Planning and Sustainable Development
CNR	National Research Council
CSP	Concentrated Solar Power
EC	European Commission
EERA	European Energy Research Alliance
ENEA	Energy and Sustainable Economic Development
EPC	Energy Performance Certificate
EU	European Union
ERDF	European Regional Development Fund
FEED	Front End Engineering Design
FiT	Feed-in-Tariff
FiP	Feed-in premium
GW	Giga Watt
GWh	Giga Watt hour
H2020	Horizon 2020
HTF	High temperature Fluid
IEA	International Energy Agency
IP	Implementation Plan
IPCEI	Important Projects of Common European Interest
IWG	Implementation Working Group
JP	Joint programme
kWh	Kilo Watt hour
LFR	Linear Fresnel reflector
LTS	Long Term-Strategy
MI	Mission Innovation
MiSE	Ministry of Economic Development
MiTE	Ministry of the Ecological Transition
MS	Member States (EU)
MUR	Ministry of Universities and Research
MW	Mega Watt
MW_e	Mega Watt of electricity
MWh	Mega Watt hour
MW_{th}	Mega Watt of thermal energy
NECP	National Energy and Climate plan

NeMESi	New Sustainable Energy Mix
NGEU	Next Generation EU
NRRP	National Recovery and Resilience Plan
PNR	National Research Programme
PONRI	The National Operational Programme "Research and Innovation"
PT	Parabolic Trough
PV	Photovoltaics
R&D	Research and Development
R&I	Research and Innovation
RdS	The National Electric System Research
RES	Renewable Energy Sources
RSE	Research on Energy Systems
SET Plan	Strategic Energy Technology Plan
SME	Small and medium-sized enterprise
STE	Solar Thermal Electricity
TCP	Technology Collaboration Programme
TES	Thermal Energy Storage
TFC	Total Final Consumption
TES	Thermal Energy Storage
TSO	Transmission System Operator

2.7 Appendices

2.7.1 References

Italy – R&I

Italian Regulatory Authority for Energy, Networks and Environment website [online]

National Recovery and Resilience Plan, mission 2 "Green revolution and ecological transition" website [online]

National Research Program 2021 - 2027 "Large Scope of Research and Innovation: Climate, Energy, Sustainable Mobility" website [online]

National Strategy for Smart Specialisation website [online]

Sfera III – Concept Note (ENEA)

The National Electric System Research website [online]

Italy – Industry

ASSOGASMETANO, "Biomethane: Italy and Europe Plant Map" [online]

Edilportale "The Fer 2 decree is coming" [online]

ENTSOE, "Project 28 - Italy-Montenegro interconnection project" [online]

Ministry of the Ecological Transition [online]

National Federation of Natural Gas for Distributors and Transporters of Vehicles website [online]

Press Regione Regione Pulgia, "Swedish company "Midsummer" investment in Puglia" [online]

Repubblica "Renewable energy: Government accelerates with the release of 18 projects" [online]

Solar Thermal World, "Superbonus has pushed solar heat in Italy" [online]

TERNA, "Climate Change" [online]

TERNA, "Tyrrhenian Link: The Double Underwater Connection Between Sicily, Sardinia and the Italian Peninsula" [online]

2.7.2 Meeting guidelines

See APPENDIX.

2.7.3 Interview guidelines

See APPENDIX.

3 Chapter 3: Germany

3.1 Structure of the document

The "Integrated Country Report – Germany" aims to provide a global and structured approach of the country's profile regarding potential interest in STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2 and WP3 concerning:

- The expressed need for manageable RES energy by the country of focus and the strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.
- The construction of a defined framework for funding and its reception by relevant audiences.
- The evaluation of performance of the funding frameworks.

Section 3.2 summarises the tasks which were carried out, both on the R&I (3.2.1) and industrial (3.2.2) sides. This gives an overview of the intelligence collected and of the key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Proposition of a reshaped funding framework based on feedback from stakeholders and the Implementation Working Group (IWG).
- Dissemination of information about the funding opportunities and impact evaluation.
- Meeting with relevant stakeholders, i.e. at Ministry, Transmission System Operators (TSO) and Regulatory Authority levels, as well as key players from local industries and civil society.
- Brokerage events with stakeholders.
- Joint industry-R&I national event.

A deeper analysis of the context of each country is provided in section 3.3, first for the research part (3.3.1) and then for the industry (3.3.2). Each of these sections provides a global overview of the different factors influencing the development of funding and commercialisation of STE applications. More precisely, it aims to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Germany.

Based on these observations, key findings are drawn in section 3.4, for both research and industry. They highlight encountered challenges and existing opportunities and finally draws a picture of the potential synergies between R&I and industry structures.

Last but not least, section 3.5 suggests strategic actions to continue opening doors for STE in Germany, from a research and industrial point of view. It finally offers an overarching approach to further support the development of STE in Germany, combining R&I and industry perspectives to offer thorough advice.

3.2 Summary of undertaken activities

Germany has been under the scope of analysis from September 2020 until August 2021. The Covid-19 global pandemic has slowed down the working process. A close cooperation has been implemented between ESTELA and DLR, and the consortium also received a strong support from the German CSP association, Deutsche CSP, to maximise impacts and meaningful results.

The following chapters will describe the work undertaken in Germany and analyse the challenges and opportunities met in the country.

3.2.1 R&I methodology

To have a wide overview of the R&I landscape of Germany, the following activities were carried out:

<table>
<tr><th>List of activities</th><th>Timeline</th></tr>
<tr><td>Stakeholders survey</td><td>Phase 1
Nov. 2019 – Jan. 2020</td></tr>
<tr><td colspan="2"><u>Aim:</u> Determine the interest and capabilities of German (and other European) stakeholders for the realisation of projects directly related to the SET-IP activities.
Description: 8 R&I topics of the SET-IP plus first-of-a-kind demonstration projects were subdivided into systems and components; potential research activities were proposed. The survey participants selected their area of competence and provided comments about the funding framework. The outcome of this exercise was provided to the consortium CSP-ERANET in order to shape the upcoming calls according to the capabilities and interests of the stakeholders.</td></tr>
<tr><td>Background research</td><td>Phase 2
Sept. 2020 – Apr. 2021</td></tr>
<tr><td colspan="2"><u>Aim:</u> To identify ongoing R&I activities, funding sources, existing infrastructure, legal framework and stakeholders.</td></tr>
<tr><td colspan="2">Description
Desk research: Revision of the SET-IP and identification of possible updates or revisions.
Update of list of projects being carried-out with participation of industrial and/or research partners.
Revision of the national funding framework.
Revision of energy policies that affect the scope of research activities.</td></tr>
<tr><td>Processing of information and writing of report</td><td>Phase 3
Sept. 2020 – Apr. 2021</td></tr>
<tr><td colspan="2"><u>Aim:</u> To write the sections devoted to R&I in this Integrated Country Report of Germany</td></tr>
<tr><td colspan="2">Description: All the information collected during the previous phases was analysed and processed by DLR in order to get the R&I landscape of Germany for CST technologies and applications, especially those directly related to the SET Plan for CSP.
The updated list of national and European R&I projects prepared by CIEMAT in 2021 within the EERA Joint Program of CSP with the inputs</td></tr>
</table>

List of activities	Timeline
	delivered by the German members of this EERA Joint Programme was also analysed to see the R&I activities currently underway in Germany and the topics covered. It was also included in this analysis the information collected by DLR from several web sites and from contact people in Greece when preparing the Deliverable D1.4 ("Report on options for financing instruments and schemes") of HORIZON-STE project. The result from this analysis is given in section 3.3.1 of this document (Overview of the context in Germany: R&I Landscape"). Key findings from this information analysis and processing are given in section 3.4.1

3.2.2 Industry

3.2.2.1 Foreseen activities and implementation challenges

To support a wider use of STE applications in Germany, ESTELA designed a general process unfolding in three steps with flexibility to adapt to the specific country challenges:

Phase 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and Germany's strategies for the development of RES in the country and for import / possible changes in the relevant framework conditions
Encountered challenges	– To find the right interlocutor – Low answer rate to interview requests – Mixed information received from different interlocutors
Applied mitigation	– Help from DLR and Deutsche CSP to identify relevant stakeholders – Send two reminders when facing unanswered requests – General translation of official documents from German to English – Confrontation of different sources with the official source
Phase 2	
BROKERAGE EVENT	
General aim	Assessment and presentation of potential solutions using CSP/STE
Encountered challenges	– Covid-19 global pandemic – Big emphasis on hydrogen
Applied mitigation	– Digging into the potential hybridisation of CSP for hydrogen production – Promoting cross-border projects opportunities
Phase 3	
JOINT NATIONAL EVENT	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	– Outbreak of covid-19 global pandemic – Not enough data collected yet
Applied mitigation	– Awaiting the end of the pandemic to evaluate the possibilities

3.2.2.2 Carried out activities

List of activities		Timeline
BACKGROUND RESEARCH		Phase 1 Sept.-Nov. 2020
Aim: To collect relevant information to better understand the energy landscape in Germany, the potential challenges for the development of STE and the needs of the country		
Description		
Desk research:	Collection of information based on available content on official websites (ENTSO-E, Pentalateral Energy Forum, Federal Ministry for Economic Affairs and Energy, Federal Network Agency (Bundesnetzagentur), AG Energiebilanzen e.V., Clean Energy Wire, etc.), academic studies or reports by consultancies, Fraunhofer ISE…	
Stakeholder mapping:	Analysis of the specific relevant departments and actors for each identified target group Exchanges with Deutsche CSP on relevant contacts and existing knowledge of the local situation	
PRELIMINARY TALKS		Phase 1 Sept.-Nov. 2020
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable renewable energy sources (RES), the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions		
Description Ideally, this phase aims to establish a first physical contact with the three key stakeholders in Germany regarding energy policy, namely the TSOs, the Ministry and the Regulatory Authority.		
TSOs:	Interview with Amprion Interview with TENNET Interview with 50Hertz	
Ministry:	Interview with BMWi	
Industry:	Interview with Siemens Energy	
PHONE INTERVIEWS		Phase 1 Sept.–Dec. 2020
Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of Germany's energy strategy and potential need for manageable RES		
Description		
Deutsche CSP:	Interview with a representative of Deutsche CSP, also Board Member of ESTELA	
BROKERAGE EVENT		Phase 2 Jan.–Aug. 2021
Aim: To have a broad overview of STE perspectives in Germany through existing and potential solutions using STE, from both the R&I and industry sides.		
Description A series of online meetings with national stakeholders were held as a mitigation measure due to the COVID-19 pandemic restrictions.		
NATIONAL EVENT		Phase 3 June 2022
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the support of German STE industries involved in foreign STE projects and concentrated solar thermal technologies for industrial heat. To focus on possible synergies and macro-economic value.		

List of activities	Timeline
Description The joint industry and R&I national event took place in-person on 30 June 2022 at Hotel Aquino, Berlin, Germany. The main conclusions and highlights of the event will be reported in the Deliverable 4.7 “Proceedings of the Joint Industry and R&I Events”.	

3.3 Overview of the context in Germany

3.3.1 R&I landscape

This section presents the main outcome of the background research and data collected from German stakeholders. It is divided into the financial framework, the ongoing activities of German participants and the strategies defined in Germany that have an impact into the focus of research and funding.

3.3.1.1 Germany's R&I support programmes

The financial support to R&I activities in the SET and CST sector are provided mainly by the following sources:

1) The 7th Energy Research Programme run by BMWi[53]: it defines the current principles and priorities for Federal Government funding for innovative energy technology. In this context, assistance is aimed primarily at technologies that meet the requirements of the energy transition. As regards the thematic priorities of energy efficiency and renewable energies, the focus is on funding measures for technologies in the fields of wind and solar power generation, a higher proportion of renewables in the heating sector through biomass and geothermal energy, energy-optimised buildings and neighbourhoods, and energy efficiency in the industrial sector. Special emphasis is placed on issues relating to the integration of new technologies into the energy system, the development of the grids, energy storage, and sector coupling.

   Since September 2018, the Federal Cabinet adopted the 7th Energy Research Programme entitled "Innovations for the Energy Transition". It contains the guidelines for energy research funding making around €7 billion available for projects. New thematic priorities are set on the basis of the following strategy lines:

   - Funding follows a more holistic and systemic approach. The focus is thus placed on research on the transformation of the energy system. It addresses the technology readiness level.
   - In addition to specific technologies, funding is made available for overarching, cross-sector issues such as energy efficiency, reduction of consumption, sector coupling and digitisation.
   - Thanks to the 'living labs' funding format, the energy system of the future can already be tested today. The results and experience serve as a blueprint for the actual practical implementation. At the same time, more funding is planned to be made available to start-ups.
   - It is essential that research is closely linked at European and international level. For this reason, cooperation with international organisations will be expanded and scientific exchange will be promoted. Furthermore, the improvement of the capacity to export and of the competitiveness plays an important role.

   BMWi's funding targets projects with a high industrial exploitation potential, therefore the research work is aligned with the needs of the industry. Funded projects preferably

[53] *7th Energy Research Programme (bmwi.de)*

include strong participation of key industrial partners, if possible as project coordinators.

This funding scheme is very flexible and adapts quickly to the industrial needs. Currently, strategic areas of research relevant to CSP include green hydrogen (see section 3.3.2.1.3), integration into process heat, thermal storage technologies, new heat transfer media (solid particles, silicon oil, molten salt), heliostat's optimisation, etc.

2) International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU): finances climate and biodiversity projects in developing and newly industrialising countries, as well as in countries in transition. The Initiative places clear emphasis on climate change mitigation, adaption to the impacts of climate change and the protection of biological diversity. In the mitigation context, IKI supports partner countries in the development and implementation of innovative instruments to reduce their greenhouse gas emissions. As such it may be principally also considered as suited for funding activities related to the IP although not explicitly mentioned in the programme. The goal is a transformation towards a sustainable and low-emission economy and supply structure. The conceptual focus is on policy advice, capacity building and suitable training measures as well as technology cooperation. The IKI projects are focusing on the increasingly important regional level in their implementation. By the end of 2017, more than 300 projects had been approved in the area of mitigation.

Exemplary funded projects can be found under https://www.international-climate-initiative.com/en/projects/

There are four IKI's selection procedures:

- In the thematic selection process, current challenges in climate protection and biodiversity conservation are usually addressed once a year. Funding priorities for these challenges are then defined, for which project outlines can be submitted. Depending on the funding priority, the funding amount per project can range from 5 to 30 million Euros.
- In country specific selection procedures BMU together with the government of the partner country develops topics for bilateral IKI projects. For these thematic funding priorities project outlines can be submitted during the competitive calls. The selection process consists of two stages and takes place in close cooperation with the partner country.
- IKI Small Grants: it has the goal to strengthen small organisations worldwide. IKI Small Grants has been supporting small projects as well as funding institutions in developing and newly industrialising countries since 2019 and promotes their capacity development. IKI Small Grants is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH and comprises the two funding lines 'Funding Institutions' and 'International Calls':
    - The funding line 'Funding Institutions' aims to support both, national and regional funding institutions, in developing their institutional capacities. In the fields of climate and biodiversity protection, they are able to efficiently absorb financial means from (inter)national donors and to implement their own call for proposals. Deutsche Gesellschaft für Internationale

Zusammenarbeit advises the funding institutions on these calls and implements targeted capacity development measures. In addition, funding of around 500,000 euros is distributed, which in part will be used to finance local projects selected by the funding institutions in the context of the call for proposals.

  - The funding line 'International Calls' regularly conducts international calls for proposals which are announced on its website and via the IKI newsletter. In a one-stage selection procedure, small sub-national, national and regional organisations based in an ODA country can apply directly for funding for the implementation of local or regional climate and biodiversity projects. IKI Small Grants 'International Calls' is aiming to fund more than 100 projects by 2025 with up to 100,000 euros each (up to 200,000 euros for mitigation and, in special cases, adaptation measures). After the first selection round, IKI Small Grants is providing three million euros for 38 selected small projects in 27 countries.

- IKI Medium Grants: addresses civil society actors based in Germany that work in collaboration with local partners in selected ODA-eligible implementing countries to put measures in place to intensify North-South cooperation on climate action, adaptation to the impacts of climate change and biodiversity conservation. IKI Medium Grants support project activities that address innovative, bottom-up contributions for implementing the Paris Agreement and the Convention on Biological Diversity. To achieve this, the BMU sets varying funding priorities each year, for which interested parties can apply with innovative project ideas.

3) Helmholtz Programme-oriented Funding: In the case of the Helmholtz Association, funding for research is organised into programmes. The Association designs these programmes in accordance with the strategic guidelines formulated by the funding partners in dialog with the Helmholtz Association. The main research centres for activities in the field of CST are the German Aerospace Center (DLR), Karlsruhe Institute of Technology (KIT) and Forschungszentrum Jülich (FZJ). Programme-oriented funding (PoF) seeks to establish a balance between cooperation and competition: Structuring the research according to research programmes enables researchers to pool their expertise across centres and disciplines and enhances their cooperation. At the same time, the programmes compete for funding. In addition to these research and development activities, Helmholtz provides large-scale scientific equipment and large platforms of its research centres for scientific communities of users that typically include members from around the world.

   For more information: https://www.helmholtz.de/fileadmin/user_upload/01_forschung/pof/EN_Factsheet_PoF_as_of_180914.pdf

4) Ministry for Innovation, Science and Research of North-Rhine-Westphalia (NRW): In Germany, the regions (Länder) are supporting the local research institutions and companies, basically to further develop the respective region. This comprises generally economic development, but also structural changes as in the case of North-Rhine-Westphalia. The former focus of heavy industry and coal power industry of this region required a lot of efforts to change its energy system, allocate new industries and foster local research for the necessary changes. NRW strongly supported the

implementation of R&D infrastructure such as the solar furnace in Cologne, the solar tower facility in Jülich, the Synlight and TESIS facilities of DLR among others. Besides infrastructure there is also a programme supporting regional R&D.

3.3.1.2 Existing R&I activities

The contributions of Germany to the SET IP have been mainly on national level though projects funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and by the German Helmholtz Society (Helmholtz-Gemeinschaft Deutscher Forschungszentren e.V., HGF). Research infrastructures have been established and funded mainly through such projects, with some additional contributions from the Fraunhofer Society (Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V., Fraunhofer).

The key data of these projects (starting on September 2017) is shown in Table 15 below.

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
EU	Predictable Flexible Molten Salts Solar Power Plant	PreflexMS	DLR	2015-2017	Non-DE: Solargis SRO, ESE ENGINEERING SERVICES FOR ENERGY S.R.L., EC SYSTEMS AMC SPOLKA Z OGRANICZONA ODPOWIEDZIALN OSCIA, COBRA, Alfa Laval OLMI	DLR, UNIVERSITAET STUTTGART Non-DE:AKADEMIA GORNICZO-HUTNICZA IM. STANISLAWA STASZICA W KRAKOWIE, CENER - CIEMAT, Agencia Estatal de Meteorologia, POLITECNICO DI MILANO, UNIVERSIDADE DE EVORA
N (NRW+BMWi)	Multi-focus tower	MFT	DLR	2015-2020	only subcontractors	DLR
EU (INEA, co-funded H2020)	Renewable PowEr Generation by Solar PArticle Receiver Driven SUlphur Storage Cycle	Pegasus	DLR	2016-2020	Non-DE: Brightsource, Baltic Ceramic, Processi Innovativi	DLR, Karlsruhe Institute of Technology (APTL/CERTH)

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
EU	Raising the Lifetime of Functional Materials for Concentrated Solar Power Technology	RAISELIFE	DLR	2016-2020	Non-DE: Brightsource, Vallourec Tubes France, AGC Glass Europe SA, Laterizi Gambettola SRL	DLR, Fraunhofer, DECHEMA Non-DE:CIEMAT, MASCIR, CNRS, Univ. Complutense Madrid, Inst. Nacional de Tecnica Aeroespacial Esteban Terradas, The Hebrew University of Jerusalem
N (BMWi)	HelioPoint (scope: heliostat qualification with drone)	HelioPoint	DLR	2017-2020	CSP Services, sbp Sonne and TeAx Technology UG.	DLR
N (BMWi)	Heliostat Qualification Juelich	HeliBo	DLR	2017-2020	CSP Services, LeiKon, Radiant Dyes	Solar-Institut Jülich (FH Aachen), DLR
N (BMWi)	Transient operation of molten salt receivers	Dynasalt-2	DLR	2017-2020	LeiKon, General Electric	RWTH Aachen, Solar-Institut Jülich (FH Aachen), DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
N (Solar-ERA.NET)	Silicone Fluid Maintenance and Operation	SIMON	DLR	2017 - 2020	TSK Flagsol, Senior Flexonics, Wacker Chemie, TÜV Nord Systems, flucon fluid control, Associated partners: innogy SE, RWE	DLR
N (BMWi)	Silicone Fluid Next Generation	SING	DLR	2020 -2022	Senior Flexonics, Wacker Chemie, TÜV Nord, EnSys, flucon fluid control, Dickow Pumpen, Associated partners: heat 11, STEAG Energy Services, RWE, TSK Flagsol	DLR
N (HGF)	Component tests for molten salt applications	ProMS	DLR	2018-2021	---	DLR
N (BMWi)	Performance Testing for heliostat fields	Heliodor	DLR	August 2018 - July 2021	CSP Services GmbH, sbp Sonne GmbH, KAM-Kraftanlagen	DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
					München GmbH, Heliokon GmbH	
N (BMWi)	Concept study CSP-Reference Plant with Molten Salt "Made in Germany"	CSPRK	DLR	March 2019 - August 2020	Steinmüller Engineering GmbH, Tractebel Engineering GmbH, MAN Energy Solutions SE, sbp sonne gmbh	DLR
EU	Solving Water Issues for CSP plants	SOLWARIS	TSK ELECTRONICA Y ELECTRICIDAD SA (Spain)	May 2018 - April 2022	---	DLR
N (BMWi)	Development and qualification of a three-dimensionally profiled absorber for the open volumetric HiTRec receiver	HiTRec3D	Kraftanlagen München	November 2018 - October 2021	Kraftanlagen München, Exentis, Continental Emitec	DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
N (BMWi) + NRW	High Performance Molten Salt Tower Receiver System	HPMS-II / SALSA	DLR	October 2018 - September 2021	MAN Diesel & Turbo SE, Flexible Industriemesstechnik GmbH Subcontracted: Salzgitter Mannesmann Forschung Associated partners: Endress + Hauser Messtechnik GmbH + CO.KG, Mannesmann Stainless Tubes, HORA - Holter Regelarmaturen GmbH & Co.	DLR and Solar-Institut Jülich der Fachhochschule Aachen.
N (BMWi)	Heliostat development with sandwich facets, carrousel tracking and optical closed-loop control	SAHEL	DLR	October 2018 - September 2021	Covestro and SBP	DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
N (BMWi)	Development of components for a solar thermal tower power plant - overall optimisation through air wall and optimised heat transfer medium	HelioGLOW	Fraunhofer	September 2018 - August 2021	LWT GmbH, NEBUMA GmbH, sbp sonne GmbH	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
N (BMWi)	Component for solar tower systems with particle cycle	KOSTPAR	DLR	December 2018 - Feb. 2020	ROBA Piping Projects GmbH, Steinmüller Engineering GmbH, MAN Diesel and Turbo SE	Forschungszentrum Jülich GmbH
N (BMWi)	Test plant for bulk material and heat	VESUW	FH Aachen, SIJ	May 2019 - July 2022	Grenzebach BSH GmbH, Hilger GmbH	Fachhochschule Aachen - Solar-Institut Jülich, Jülich
N (BMWi)	Secondary reflector for solar tower	SolSec	Fraunhofer	May 2019 - April 2021	---	DLR, Fraunhofer-Institut für Solare Energiesysteme (ISE)

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
N (BMWi)	Optimisation of Operation of Molten Salt Parabolic Trough Systems	MS Opera	TSK Flagsol	June 2019 - Nov. 2021	TSK Flagsol Ass. Partner: Innogy SE	DLR Non-DE: UniEvora
N (BMWi)	Upscaling & manufacturing of volumetric air receivers	FerVoRec	Kraftanlagen München	September 2019-2022	Kraftanlagen München	DLR
N (BMWi)	Life-time optimised operation of molten salt receivers	LOBSTeR	MAN Energy Solutions	October 2019-2022	MAN Energy Solutions	DLR
N (BMWi)	Development and validation of a new volumetric air receiver	VokoRec	DLR	October 2019-2022	Kraftanlagen München, Eugen Arnold GmbH	DLR
EU + N (NRW)	Heliostat prototype demonstration	HelioNRW	DLR	June 2019 - December 2021	Heliokon GmbH and Hilger GmbH	DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
N (BMWi) + Solar-era-net	Novel online flow density and temperature measurement systems for monitoring and operation optimisation of external tube receivers	TubeMon	DLR	September 2019 - August 2022	Non-DE: CSP Services Espana, Brighsource Industries) Associated partner: CSP Services GmbH	DLR
EU	High storage density solar power plant for flexible energy systems	HIFLEX	KT Kinectics Technology	September 2019 - August 2023	HelioHeat GmbH No-DE: NextChem, Barilla Group, Sugimat, Tekfen, John Cockerill	DLR
N (BMWi)	Particle receiver test with maximal solar flux density	noLimints	DLR	October 2019 - September 2022	---	DLR
EU	Components' and materials' performance for advanced solar supercritical CO2 power plants	COMPASsCO2	DLR	November 2020 - October 2024	Non- DE: John Cockerill, Sugimat, OME	DLR, Forschungszentrum Jülich, DECHEMA Non-DE: Ciemat, University of

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
						Birmingham, VTT, OCAS, CVR
N (BMWi)	Efficient control of solar fuel production with DNI Nowcasts	SolarFuelNow	DLR	2020-2023	CSP Services, Strauberg & Vosding	RWTH, DLR
N (BMWi)	Electric heating for PHES plants	E-HEAT	DLR	2021-2023	Vulcanic, Schniewindt, Kraftanlagen München	
N (BMWi)	Increasing the cost efficiency of liquid salt receivers	STERN	MAN Energy Solutions SE	2020-2024	Salzgitter Mannesmann Forschung GmbH, MAN Energy Solutions SE	Forschungszentrum Jülich GmbH, DLR, FH Aachen
EU	Energy efficient, primary production of manganese ferroalloys through the application of novel energy systems in the	PreMa	SINTEF	2018-2022	Outotec	Helmholtz-Zentrum Dresden-Rossendorf

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
	drying and pre-heating of furnace feed materials					
EU (through N-NRW)	Further development and construction of an automated plant for solar-thermochemical hydrogen production on a solar tower	ASTOR-ST	Rheinischen Fachschule Köln (RFH)	01/2022 - 12/2022	Stausberg & Vosding GmbH	DLR, RFH
N (BMWi)	All sky imager based solutions for CSP plant control	WobaS-A	DLR	12/2018 – 10/2021	CSP Services, TSK Flagsol Engineering GmbH	DLR
N (BMWi)	Super-critical CO2 as alternative working medium for solar-thermal applications.	Carbosola	Siemens	10/2019 – 09/2021	Siemens Energy	DLR, Helmholtz-Zentrum Dresden-Rossendorf, Technical University of Dresden
N (BMWi)	Integration of CSP and PV systems	IntegSolar	DLR	10/2019 – 09/2021	Suntrace	DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
EU+N (NRW)	Power to heat technologies with molten salt storage for application in industry and CSP-PV hybrid power plants	SWS	DLR	05/2018 – 07/2021	TSK Flagsol	DLR, Solar Institute Julich
N (BMWi)	Concept study for a molten salt tower reference power plant made in Germany	CSP Referenzkraftwerk	DLR	03/2019 – 12/2020	MAN Energy Solutions, sbp sonne GmbH, Tractebel Engineering GmbH, Steinmüller Engineering GmbH	DLR
N (BMWi)	High Performance Solar 2	HPS 2	DLR	07/2016 – 11/2021	TSK Flagsol Engineering GmbH, Eltherm, Yara, Steinmüller Engineering, Innogy	DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
N (CSP Eranet) (BMWi)	European Parabolic Trough with Molten Salt	EuroPaTMoS	DLR	12/2020 – 11/2023	TSK Flagsol, CSP Services	DLR
N (BMWi)	Component tests with molten salt under application-relevant operation conditions, based on requirements for tower and line focus systems	MSComp	DLR	7/20219 – 12/2021	---	DLR
EU	New StOrage Latent and sensible concept for high efficient CSP Plants	NewSOL	University of Évora	1/2017 – 7/2021	---	DLR
N (BMWi)	Development of processes for thermal nitrate salt storage for increased temperature and lifetime.	VeNiTe	DLR	2020-2023	Flagsol, MAN, RWE	DLR

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	German (DE) Industrial Partners	German (DE) R&D Partners
N (BMWi)	Key components for next-generation molten metal and molten salt heat storage systems	LIMELISA	KSB	2021-2024	KSB	DLR
N (BMWi)	Moving Barrier Thermocline molten salt single-tank storage tank	MoBaCline	Flagsol	2019-2022	Flagsol	DLR
EU CSP.Eranet	Improved thermocline concepts for thermal energy storage in solar thermal power plants.	Newcline	Univ. Barcelona	2020-2023	Kraftblock	DLR

Table 15: R&D Projects with involvement of Germany since 2017 relevant to the SET IP

Due to the importance of sector coupling, BMWi supported the funding of DLR's new Institute for Future Fuels. The vision of the DLR Institute of Future Fuels is to develop technological solutions for harvesting large amounts of solar energy in the sunbelt regions of the earth and use it together with the renewable resources water and air to produce fuels cost efficiently. From this vision the mission of the Institute evolves to develop materials, components and processes for solar fuel production, simulate them, scale them up, and analyse them techno- socio-economically. The Institute of Future Fuels will cover the whole development chain to provide solar fuels. It is structured into four areas:

1) Basic research to develop new reactive materials necessary for the fuel syntheses;
2) Development of processes, components and reactors for integration of heat and mass flows;
3) Scale-up of processes and analyses of plants by digital twins as well as support of the industry in implementing the processes;
4) Techno- and socio-economic evaluation of processes and logistic concepts for the optimised integration of solar fuels in the global market.

Furthermore, German funds have been provided to install, operate and maintain infrastructure required for testing, developing and demonstrating new CST technologies. Table 16 summarises the infrastructure currently available in Germany.

Name	Location	Owner	Description
Solar Tower Jülich	Jülich, Germany	DLR	It goal is to research, develop and demonstrate solar tower components such as heliostats and receivers. Demonstration plant: 10 hectares area, more than 2,000 heliostats, 60 m high solar tower, 22 m² solar volumetric air receiver, atmospheric air can be heated to about 800 °C, electric power capacity 1 MWe. On this tower, a section is dedicated to research projects, e.g. to test innovative receiver systems. A new "multi-focus tower" (July 2020) offers three levels to be used for research purposes.
Synlight	Jülich, Germany	DLR	Solar simulator that provides radiation power of up to 310 kilowatts and two times up to 240 kilowatts in three separately usable radiation chambers. Its focus is the development of production processes for solar fuels. In addition, researchers and industrial partners in the solar thermal power plant or aerospace industries find ideal conditions for tests using full-size components.
Solar Furnace	Cologne, Germany	DLR	The high flux solar furnace concentrates sunlight for different research purposes while

Name	Location	Owner	Description
			irradiances up to 5 MW/m2 and temperatures above 2500 °C are possible. These procedures are aimed primarily at the chemical storage of solar energy and its application in chemical, technical and metallurgical high-temperature processes.
QUARZ®-Center	Cologne, Germany and CIEMAT's Plataforma Solar de Almería	DLR & CIEMAT	Laboratories for the measurement and qualification of key components for CST. Offers independent quality tests of components and systems to developers, producers, customers, and suppliers of thermal solar power plants. Used to evaluate among others, the orientation and compatibility of components such as mirrors, receivers, and support structures. Provided quality certificates that increase the competitiveness of components and systems, helping investors to reduce their risks.
CeraStorE	Cologne, Germany	DLR	Infrastructure to research on new storage materials and ceramics. Its aim is on basic research for innovative materials as well as on application-oriented issues in collaboration with industrial partners. Applications include, for example, thermal energy storage systems, solar power plants in baseload operation or efficient gas turbines. Part of CeraStorE is the TESIS facility dedicated to the test, qualification and demonstration of components and systems for thermal energy storage with molten salt.
HeliTep	Jülich, Germany	DLR	Heliostat testing platform with a surface area of around 1,260 m², used for individual heliostat qualification under operating conditions. The metrological scope of services of the test platform mainly includes the determination of shape and structure accuracy, the determination of tracking accuracy and reflectance, the measurement and simulation of the influence of external loads (wind, temperature, gravitational force) and the characterisation of the reflected focal spot as well as the investigation of structural properties.
REPA test facility	CIEMAT's Plataforma Solar de	DLR & CIEMAT	Used to investigate the service life and failure mechanisms of flexible pipe connections. At this facility, the temperatures, pressures, mass flows and cyclical mechanical

Name	Location	Owner	Description
	Almería, Spain		movements of parabolic trough power plants can be accelerated in endurance tests. For this purpose, the movements of parabolic trough collectors - rotation and translation - are simulated and the operating temperatures and pressures are generated via a heat transfer system.
METAS	CIEMAT's Plataforma Solar de Almería, Spain	DLR & CIEMAT	The main parameters measured in the Meteorological Station for Solar Technologies (METAS) are: direct normal irradiance (DNI), the dynamic effects of clouds on the solar resources, effect of aerosols on power plants (soiling and attenuation of the solar radiation), spectral irradiance, dynamic wind load on collector structures and receivers and circumsolar irradiance. To improve the data base for project developers, standards and guidelines for the generation of bankable solar radiation data is developed here. Additional measurements are performed on sites in Jülich, Cologne and the Middle East and North Africa to evaluate the conditions in these regions.
KONTAS	CIEMAT's Plataforma Solar de Almería, Spain	DLR & CIEMAT	Outdoor test facility where parabolic trough modules and receivers can be tested under realistic operational conditions. A heating and cooling unit enables tests with thermal oil from 20°C to 390°C and the azimuth track enables testing of the receiver at all relevant incidence angles.
OPAC	Cologne, Germany and CIEMAT's Plataforma Solar de Almería	DLR & CIEMAT	Laboratory provided with the equipment to characterise the materials used as reflectors in solar concentrating systems. It also tests the accelerated ageing of solar reflectors with the purpose of predicting in a short time the behaviour of these materials during their useful lifetime. Along with this indoor equipment, there are a series of outdoor test benches for exposing materials to outdoor weather conditions and comparing their degradation with those found in the accelerated ageing tests. In addition, a heliostat test bench was recently installed to test the influence of blocking on the coatings lifetime.
Fraunhofer Institute for	Freiburg, Germany	Fraunhofer ISE	It includes different laboratories for the research and qualification of CST

Name	Location	Owner	Description
Solar Energy Systems			components and systems (in addition to PV), such as the Concentrator Optics Laboratory and Field, CD-Lab for accelerated aging tests, TES-Lab for characterisation and simulation of thermal storage materials, and the Water Treatment Laboratory.
Évora Molten Salt Platform (EMSP)	Évora, Portugal	University of Évora	Molten salt parabolic trough test facility owned by the University of Évora and jointly operated with DLR. The test infrastructure was mainly co-funded in the framework of two research projects, HPS and HPS2, by the German Ministry of Economic Affairs and Energy (BMWi). Water-run and hot commissioning will be performed in summer 2021. Beyond the initial goals of HPS2, the EMSP facilitates a wide range of component tests and system demonstration, advancing the transfer of molten salt innovations into market-ready applications. This includes qualification and optimisation of subsystems and components, proof and improvement of plant safety, reliability, and maintainability, as well as optimisation of operation and control for enhanced performance and economics.

Table 16: CST infrastructure available in Germany

3.3.1.3 National and International Cooperation

Germany has a strong interest to make significant contributions towards upcoming markets. The re-launch of CST/STE in Europe, e.g. in Spain, will play an important role for Germany´s industry and research stakeholders. Research projects with European partners are highly supported (Evora Molten Salt Platform, Plataforma Solar de Almería, Demonstration of CSP for Process Heat at Barilla plant, etc.)

In international markets Germany supports projects with the vision of a strong role of national stakeholders as export nation.

The import of green energy such as hydrogen for a future decarbonised energy supply is also supported. Germany requires such resources for its industry sector as well as for mobility and heating and is providing increasingly budgets in recent times to develop the green technologies that will play a future role in the energy supply of the country, even from third countries.

3.3.2 Overview of the context for industry

The desk research and the preliminary interviews helped ESTELA refine its understanding of the energy context in Germany. The following subsections were enriched thanks to ESTELA's own desk research and inputs from the following stakeholders: the German CSP association (Deutsche CSP), three out of the four TSOs (Amprion, Tennet and 50Hertz) and the Federal Ministry for Economic Affairs and Energy (BMWi). Deutsche CSP has been particularly helpful, facilitating the contacts between Horizon-STE's consortium and the Ministry and providing us with a thorough context of energy policy and interests in Germany.

3.3.2.1 Energy policies and political strategies in the German landscape

3.3.2.1.1 Current energy mix in Germany

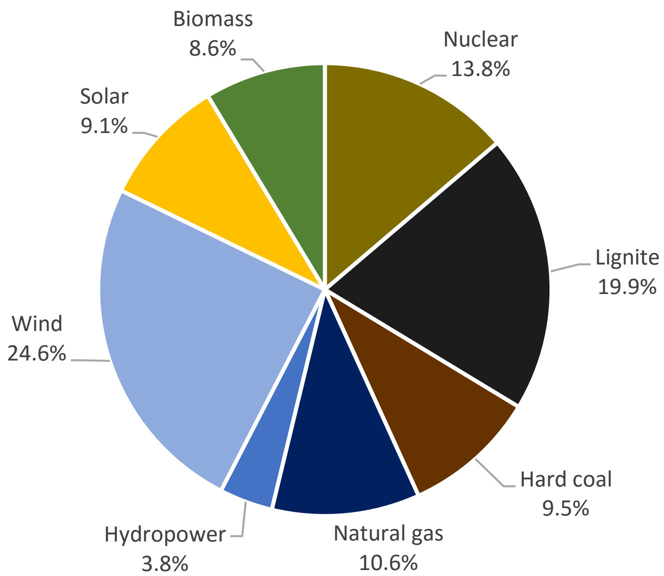

Figure 20: Power generation in Germany in 2019 (source: Fraunhofer ISE)

As shown in Figure 20Figure 20: Power generation in Germany in 2019 (source: Fraunhofer ISE), in 2019, fossil fuels represented 39.4% of power generation and nuclear 13.8% in Germany, while renewables accounted for 46,6%, ranking as first energy source. Wind represents on its own almost a quarter of the German power generation in 2019. The initial PV cap which was limiting the integration of 52GW of PV in the German energy mix has been lifted in 2020, allowing the solar sector to grow further.

Figure 22 shows the provisional data for energy consumption per sector in 2019. The three main energy consuming sectors are transport, industry, and private households, all three of them accounting for 85% of the total energy consumed in Germany. More precisely, the breakdown of energy sources per sector is displayed in Figure 21. The share of fossil fuels accounts for almost half of the industry sector and for almost the totality of the transport sector and is also very present in households' consumption. This leaves space for further penetration of renewables in the different sectors.

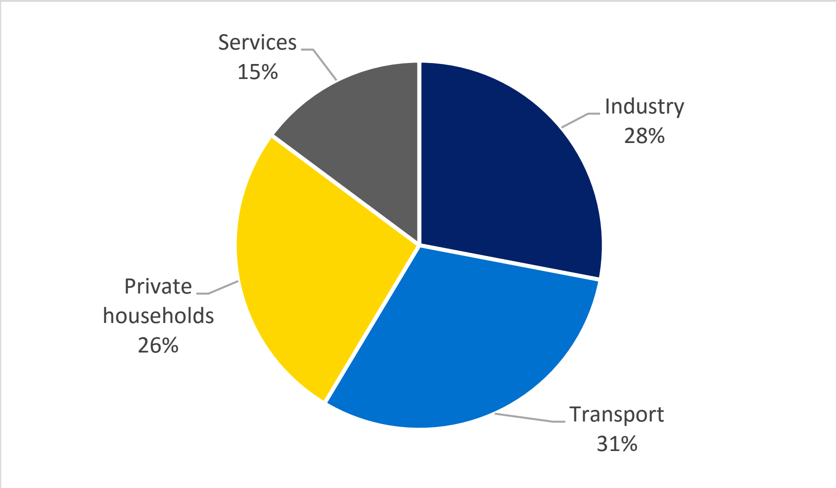

Figure 22: Energy consumption per sector in 2019 (source: AG Energiebilanzen)

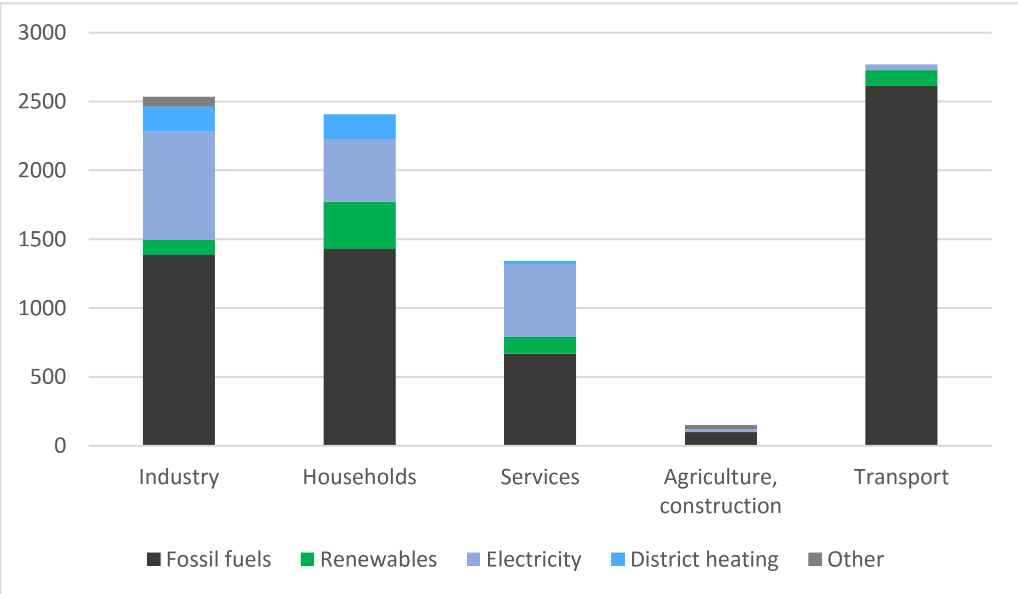

Figure 21: Breakdown of energy sources in final consumption by sector (units in PJ)

Regarding electricity production, renewables already represent a major share of the German mix. Table 17 shows the total installed capacity per technology in Germany for electricity production. Onshore wind and PV have the largest installed capacity in the country, the two of them representing almost 50% of the total installed capacity.

Technology	2019 installed capacity (GW)
Natural gas	29.9
Hard coal	22.8
Lignite	21.1
Oil	4.4
Nuclear	9.5
Onshore wind	53.4

Technology	2019 installed capacity (GW)
Photovoltaics	49.2
Offshore wind	7.5
Biomass	8.2
Hydropower and others	4.8
Total	210.6

Table 17: Total installed capacity in 2019 (source: Fraunhofer ISE)

Germany is a net energy importer, as shown in Table 18Table 18, for almost every energy source (including nuclear), except renewables and electricity.

German energy exchange balance in 2019 (in PJ)	
Import	13,254
Export	3,747
Net import	9,507

Table 18: German energy exchange balance in 2019 (source: AG Energiebilanzen)

On 1st January 2021, the new Renewable Energy Act (EEG) came into effect[54]. This document previously established grid priority for onshore wind, solar PV, and biogas and guaranteed them feed-in tariffs. It now includes the German Hydrogen Strategy and electricity pricing for e-car charging.

The EEG 2021 foresees "innovative auctions" to tender an additional 500-850 MW per year. Not technology-specific, one of the aims of these tenders would be to combine technologies to bring more stability to the system. Table 19 summarises the foreseen tendering capacities between 2021 and 2028.

Tender volume	2021	2022	2023	2024	2025	2026	2027	2028
Onshore Wind	4500 MW	2900 MW	3000 MW	3100 MW	3200 MW	4000 MW	4800 MW	5800 MW
Offshore Wind*	950 MW	905 MW	900 MW	2900 MW	3500 MW			
Solar PV	2150 MW	1900 MW	2000 MW	2000 MW	2050 MW	1950 MW	1950 MW	1950 MW
Biomass	600 MW	600 MW	600 MW	600 MW	600 MW	600 MW	600 MW	600 MW
Biomethane	150 MW	150 MW	150 MW	150 MW	150 MW	150 MW	150 MW	150 MW
Innovation tenders[1]	500 MW	600 MW	600 MW	650 MW	700 MW	750 MW	800 MW	850 MW

Table 19: Annual tender volume for renewable installations in Germany (Source: EEG 2021)

[54] *Source: Clean Energy Wire, "What's new in Germany's Renewable Energy Act 2021", 6 Jan. 2021 [online]*

The EEG 2021 is also suggesting specific measures to encourage the development of wind and biomass in the South of Germany, introducing a "quota":

- 15% of the successful wind installation tenders must come from the South between 2021-2023, and 20% from 2024 on.
- 50% of successful biomass installation tenders must come from the South.

The "grid congestion zones" disappeared in the document, since they did not work, according to the Ministry. In addition, the "quota for the south" is expected to help reduce the imbalance generation capacity between the north and the south of the country, also observed by the TSOs (see section 3.3.2.2).

The EEG 2021 also foresees more flexibility from part of the RES generation, to avoid negative power prices. To do so, these installations would not receive their feed-in remuneration if the spot market price is negative for four hours (the limit was previously of six consecutive hours).

Finally, regarding renewable hydrogen, the new Renewable Energy Act foresees to (partially) exempt producers of green hydrogen from having to pay the renewables surcharge on the power they use, provided that they use renewable power installations that have not been subsidised via the EEG.

3.3.2.1.2 The German NECP and the potential for STE

Germany has submitted an ambitious National Energy and Climate Plan (NECP), with a greenhouse gas emission reduction target of 38% by 2030 compared to 2005, and the aim to reach a 55% decrease compared to 1990.

More precisely, Germany set the following targets for 2030:

- 30% of renewables in its gross final energy consumption.
- 65% if renewables for electricity generation.
- 27% of renewables in the heating and cooling systems.
- 27% of renewables in the transport sector, even though this is only a projection, as no national target has been set up for this sector.

To maximise its chances to reach these objectives, Germany foresees an extension of its renewables installed capacity by 2030, planning to almost double its PV installed capacity in ten years. Offshore wind is also expected to undergo an important increase, while the development of onshore wind will not be as impressive. Table 20 gives a detailed overview of the capacity targets for 2030, as mentioned in the NECP. These targets have been supported in the new Renewable Energy Act 2021 which entered into force in January 2021.

Technology	2030 installed capacity (GW)
Onshore wind	67-71
Photovoltaics	98
Offshore wind	20
Biomass	8.4
Hydropower and others	6

Table 20: Prevision of renewable installed capacity in 2030 (source: NECP)

Even though the NECP highlights that the sectoral technology mix will be flexible, a high share of variable renewables seems to remain predominant in the future German mix.

Regarding the heating sector, Germany plans to replace all coal cogeneration with gas cogeneration, and to reduce coal-fired power generation. In this regard, there is an existing pilot project, by DLR, Vattenfall and the start-up SaltX, to develop a 10MW salt battery at the Reuter plant, in Berlin[55]. This plant initially supplies 600,000 households with heat in Berlin. This concept of Carnot battery[56], developed by DLR, could be a solution to green the heat networks. A lot of heating is currently produced by coal generation plants in Germany, which will slowly disappear by 2030, with the ultimate deadline of 2038 for Germany to phase out of coal. Germany has set a target of 30% of renewables in its heating networks by 2030. Even though the German NECP plans to have renewable heat mainly powered by biomass and renewable waste, this Carnot battery project may open the way for thermal energy storage.

Germany also plans to look into advanced biofuels for the transport sector, with a target of 1.75% (single counting) by 2030. The country will focus on developing liquid and gaseous renewable fuels from biomass, mostly from waste materials and residues and is targeting a large-scale production in biogas and synthesis plants. E-mobility, including the possibility of fuel cells, is also analysed in the frame of the Pentalateral Energy Forum (which gathers the Netherlands, Austria, Germany, France, Luxembourg, Switzerland, and Belgium). The main covered topics in this Forum are:

- Market integration, to increase cross-border trade on the intra-day market and also cross-border projects.
- Flexibility, for which hydrogen, load management and P-to-X might play a key role. The Forum also mentions that storage systems and e-mobility will also be an important aspect for increased flexibility. A special mention is made on analysing "specific electricity-related to sectoral coupling".
- Reliability of supply.
- Possible financing instruments, such as joint approaches with the European Investment Bank, to lower risks and give more chances to the countries to achieve their objectives.

Discussing with the Federal Ministry for Economic Affairs and Energy made the perspectives for STE clearer. Since Germany is currently looking at sector integration, the potential of a technology to bridge different processes is attractive. If this potential could be proved for STE, the interest from the German Ministry would significantly increase. In the frame of the hydrogen strategy (see section 3.3.1.3), new funding opportunities to support EU-wide and worldwide projects are made available. STE is eligible for these funding, since it could open opportunities in other countries which would benefit German companies and research institutes. To that extent, BMWi is interested in visiting facilities

[55] Source: Energy Transition, 15 May 2019 [online]

[56] The Carnot battery appears as a promising new concept for electricity storage, using an electric heat pump to convert the surplus energy produced by variable renewable sources into heat, which is then stored in water or liquid salt, and turned back into electricity when required via a modern steam engine and generator

in Spain. This opening of real market opportunities benefitting German companies is a *sine qua non* condition for STE projects to be funded by the Ministry.

3.3.2.1.3 Hydrogen Strategy

Germany published in June 2020 a National Hydrogen Strategy[57] regarding the generation, use and transport of hydrogen. €7 billion were allocated by the German state. The strategy foresees collaboration between different sectors and different applications. The overall aim is to make hydrogen competitive and to be able to use it nationally and internationally. The framework will be updated on ongoing basis.

The strategy contains 38 measures, amongst which 4 are included in European activities and 5 in an international hydrogen economy perspective. The others are covering the following areas: hydrogen production, hydrogen use, infrastructure and supply, research, education, and innovation. The idea is to start a market ramp-up from 2020 to 2023, and then strengthen this ramp-up from 2023 to 2030.

The current total power-to-gas capacity in Germany reached 55MW, of which 33.7MW are still at a planning stage. The aim is to reach 5GW of electrolysers installed capacity by 2030 and to add another 5GW to it by 2035, with a focus on local deployment, to create a local economy. Offshore areas will also be assigned for further green hydrogen production. On the international side, a system of guarantee of origin for green hydrogen will be supported by the German government and the development of the European Regulation for standards. Joint research will be intensified at EU level, for example through joint cross-border projects.

The German Energy Transition ("*Energiewende*") policy targets a penetration of 65 % RES in the electricity sector by 2030. However, the targets to decarbonise the industry, heating, and mobility sectors will be challenging to meet. During the discussion with the Ministry for Economic affairs and energy, representatives from the Ministry shared their conviction that H_2 will play a big role to reach this target across sectors.

According to the same BMWi's report, "hydrogen offers both a growing industrial policy potential and an opportunity to support the German and European economy in coping with the consequences of the coronavirus pandemic. The aim of the National Hydrogen Strategy (NWS) is therefore also to exploit the associated economic opportunities."

The strategy document lists existing government programmes supporting hydrogen technologies and adds that "the stimulus package agreed on 3 June 2020 provides for a further 7 billion euros to be made available for the market ramp-up of hydrogen technologies in Germany and a further 2 billion euros for international partnerships. From today's perspective, it will not be possible to produce the large quantities of hydrogen that will probably be needed for the energy transition in Germany, since renewable generation capacities within Germany are limited. Germany will therefore have to remain a major energy importer in the future. This is why we will establish and intensify international cooperation and partnerships around the topic of hydrogen."

[57] *Available in full here: https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/die-nationale-wasserstoffstrategie.pdf?__blob=publicationFile&v=14*

This is also why any progress towards competitive uses of CSP power in the context of establishing a new hydrogen market finds interest in Germany.

3.3.2.2 The energy transmission system: towards smart sector integration

Given the situation in Germany, it would be more accurate to talk about energy transmission systems in a plural form. Indeed, the German network is divided into four entities, which have each a geographical area: Amprion, 50Hertz, TENNET, and TransnetBW.

ESTELA contacted the four German TSOs and received feedback from three of them. Each has its own strategy and priorities, due to different grid locations, but they still share some common concerns to ensure the good performance of the system:

- Back-up by conventional plants.
- Batteries.
- Location of storage systems.
- Gas and green hydrogen.

Germany is putting smart sector integration at the heart of its current approach of its energy system. TSOs are aware of the further penetration of variable renewables in the energy mix and of the challenges this implies. However, there is a consensus around conventional plants, which are able to deliver back-up energy when needed, in a cost-effective way. However, as the German government plans to phase-out from coal and to close coal power plants by 2038, an alternative will be needed. Currently, the strategy is to focus on including as much renewables as possible, mostly variable, to the grid. Depending on the geographical area, the point of focus can be on PV, onshore wind, or offshore wind. According to ESTELA's interlocutors, without massive investments in storage capacities, the installation of about four times the power demand would be needed to ensure that enough energy will be generated at any time and would allow dealing efficiently with reliability issues.

The latter is a key issue for German TSOs and is closely link to the problematic of sector coupling. To avoid curtailments due to an increase of the load, three solutions are offered to TSOs:

- To strengthen interconnectors.
- Explore storage solutions: if batteries cannot fit system perspectives, they could be useful for more decentralised used. However, the question of seasonal storage needs to be assessed, particularly to store the surplus of wind.
- To use the surplus which cannot be integrated to the system for power-to-gas solutions.

The approach of batteries changes from one TSO to the other. If some do not consider them at all at system level and consider them for more decentralised uses, others could see them play a role in system stability. According to the Network development plan 2019-

2030, batteries will be placed "behind the congestion to ensure electricity supply"[58]. All TSOs agree on the crucial point of location for these storage capacities. If batteries can only have input and output at the same place, power-to-gas can have its input in one place and deliver to consumers in another location. This would prove very valuable in Germany, in particular to carry the power from the North, where a lot of energy is produced, to the more populated South of the country.

ESTELA brought up the concept of Carnot battery, as a potential help for system stability, particularly to compensate the decrease of conventional power. Despite being developed by DLR, the Carnot battery is not yet considered by TSOs as an advantage for the grid. The matter of cost remains the priority especially compared to those of existing assets in gas.

Regarding power-to-gas, every TSO is interested in the opportunities which can be provided by hydrogen. However, all of them insisted on the necessity of only using surplus of renewables to generate this hydrogen. They contributed to write ENTSOE's Multi-sectorial planning support Roadmap[59]. It is key to cross different views, when assessing the value of interlinks, especially regarding hydrogen production.

As highlighted by one TSO, what matters to businesses is the potential duration (electrolysers can run 8,000 hours) and the possibility to get green certificates from that. The main challenge, at the moment, is the difference of CO_2 prices amongst different sectors, which makes it complicated for TSOs to connect those different sectors while ensuring a proper reduction of emissions.

3.3.2.3 The German industry: a current leader in STE

ESTELA also conducted an interview with a main industry stakeholder (SIEMENS Energy) that revealed the current expectative approach of industrial stakeholders in Germany related to the possible deployment of CSP in the country.

CSP is seen as difficult to promote, since its assets related to stabilising the grid and adding dispatchability are currently not valued – neither in the auction design nor by the operating TSOs. Without a proper mechanism to put numbers on this "system value" of CSP and consider the effective cost shifts that variable renewable sources incur to the global system costs - which would at least partly mitigate its higher costs compared to PV and wind on-shore - CSP will not be able to enter the German generation market.

Siemens Energy considers just for any technology sector in its initial deployment phase in any country, a specific institutional / regulatory framework allowing the demonstration of CSP system value as mandatory trigger towards a better use of this technology.

Siemens Energy opined that CSP might play a role as well in the context of the establishment of a new hydrogen market, but noted that CSP is not yet explicitly mentioned in the National Hydrogen Strategy of the German Government, for example via hydrogen shipped from countries with best solar resources. However, import scenarios for electricity have been for the time being dropped.

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[58] *Source: Bundesnetzagentur, "Bundesnetzagentur approves network development plan 2019-2030", 20 December 2019 [online]*

[59] *Available online: Multi-sectorial planning support Roadmap by ENTSO-E*

Siemens Energy confirmed that there is a strong need for process heat in Germany and that CSP process heat could be a potential part of a future process heat production mix. There are big industries and big industrial component providers in the country, which constitute a large market that could explore an integration of heat storage and backup systems or the mutualisation of energy sources.

Siemens Energy confirmed its interest in the potential of thermal Storage and Carnot batteries considered as essential players in Siemens Energy's Decarbonisation Portfolio that might serve Siemens Energy's customers in their decarbonisation targets. In the long run, Siemens Energy expects a mixture of technologies for storage, with batteries for the 4–5-hour range and thermal storage for beyond 6 hours that would support the decarbonisation of existing conventional power plants and high temperature industrial applications.

3.4 Key findings

3.4.1 R&I

3.4.1.1 Germany has a strong and sustainable R&I support programme

The following sources provide financial support to German R&I activities in the SET and CST sector:

- 7th Energy Research Programme of the BMWi (Federal Ministry for Economic Affairs and Energy): helps companies and institutions to develop technologies for the energy supply of tomorrow. Assistance is aimed primarily at technologies that meet the requirements of the energy transition. CSP/STE activities are eligible for these funds. The yearly provided funds are around 7 million Euros.
- International Climate Initiative of the Federal Ministry for the Environment, BMU: finances projects on climate change mitigation, adaption to the impacts of climate change and the protection of biological diversity in developing and newly industrialising countries.
- Helmholtz Programme-oriented Funding: structures research according to research programmes, enabling to pool expertise across research centres and disciplines and enhances their cooperation. At the same time, the programmes compete for funding. It also provides funds for large-scale scientific equipment and large platforms.
- Ministry for Innovation, Science and Research of North-Rhine-Westphalia (NRW): NRW supports the implementation of R&D infrastructure for CST as well as regional R&D activities.

3.4.1.2 R&D and Industry roadmaps are well aligned

Based on Germany´s political agenda to realise the energy transition from fossil to renewable energy use, the main funding programme, i.e. the BWWi 7th Framework programme, demands a high share of industrial partners in any R&D project. As such, the programme supports a quick market introduction by focussing on high TRL. The higher the TRL to be achieved in a project the higher the industry share in the project must be.

To fulfil these conditions, the R&D and the industry sectors are cooperating very closely in R&D projects; therefore, their roadmaps are well aligned.

3.4.1.3 Enable the future national energy supply with renewables

Main focus of supported R&D activities is to enable the future national energy supply with renewables. Even if storage capacities for electricity are actually not yet needed in the German electricity market, R&D to develop storage technology is strongly supported by BMWi and is seen as a key to solve the future dispatchability demand either by CSP/PV with thermal storage or, alternatively, with electrical batteries. By now, the option to rely on CSP/PV with thermal storage is seen as a promising candidate to solve the problem of fluctuating renewable sources as there is still a huge cost reduction potential.

Even though the main funding has been in the past on tower technology and parabolic troughs for electricity production, Germany´s R&I funding is generally open for all CSP/CST technologies as long as they follow the strategic plan of the programme, i.e. the reduction of greenhouse gases, for instance through the application of CO_2-free process heat technologies, where CST will play an important role.

3.4.1.4 Support R&D for technology assets as an export nation

Germany supports the European and international research activities for both its industry as well as research entities aiming at supporting Germany´s role as export nation. As Germany has a strong export industry and many companies are well established to provide goods in international markets, the renewable sector is young but at the same time a very promising and rapidly growing technology sector which may generate revenues and jobs in Germany. As an example, German companies provided around 40% of the supplies for the NOOR1 power plant in Morocco which may be seen as a huge success of this policy.

3.4.1.5 Germany supports activities towards future green energy imports

The import of green energy such as hydrogen for a future decarbonised energy supply is highly supported. Germany requires such resources for its industry sector as well as for mobility and space heating. In the past, the energy supply was partly realised from fossil energy from outside Germany and even Europe, i.e. coal from South Africa, natural gas from Russia, liquid gas from USA, etc. The future supply with renewable energy will most probably also be based up to a certain amount on the imports. R&D projects in the past investigated the use of renewable technologies together with partners from countries with a higher amount of sunshine hours or higher wind levels than those in Germany. This involves the option to import cheaper energy produced in those countries than if it was produced in Germany. Strategic partnerships were established with those countries to support the local industrial development by technology transfer and joint R&I projects. It is expected that these partnerships and others will be strengthened in the near future.

3.4.2 Industry

The question of adding flexibility to the electricity system is not yet perceived as urgent issue by the German TSOs, since backup can be ensured by gas power plants. However, ESTELA identified some interest concerning the potential of STE for sector integration and hydrogen production in sunny countries. The key issue will be to demonstrate, through concrete projects, how STE could contribute to the decarbonisation of the industry, heating, and transport sectors.

To ensure that the following key findings can be effectively transformed into key actions, it is necessary that the political/regulatory conditions send convincing signals to the industry sector.

As one of the important levies for action is that BMWi called the CSP sector to be informed about on-going developments and the industrial potential of the entire STE value-chain for uses beyond electricity generation. In other words, the Ministry expects to be convinced by the industry of the added value of STE. Accordingly, the industry already provided by ESTELA and Deutsche CSP in February 2021 some information on possible pathways to projects involving SMEs and especially their export business. The industry hopes that it will soon receive the adequate support to present such projects that might consist in calls for expression of interest, local tendering, direct subsidies or support for business worldwide.

3.4.2.1 Germany is looking in priority into sector integration

The perspective of smart sector coupling is thereby one of the primary points of focus of the German energy policy, to make the best use of all technologies.

With the closing of coal power plants, Germany needs a firm plan to reach the targets it included in its National Energy and Climate Plan for 2030:

- 30% of renewables in its gross final energy consumption.
- 65% if renewables for electricity generation.
- 27% of renewables in the heating and cooling systems.
- 27% of renewables in the transport sector, even though this is only a projection, as no national target has been set up for this sector.

If, for the electricity sector, Germany is already on tracks and keeps on developing its PV and wind technologies, the rest of the sectors are still highly depending on fossil fuel generation. An example of projects which will allow to decarbonise industry heat is the HiFlex project (HiFlex – Secure & Flexible (hiflex-project.eu)). Also the Carnot battery project, led by DLR, should be tested. Whenever the potential of STE as a cross-sector technology would be seen as demonstrated, the BMWi would then increase its interest in the STE technology looking more specifically into solutions that started to be explored such as:

- Combination with other technologies for district heating and process heat for plants in the food, beverage and pharmaceutical sectors, also for airports.
- Industrial projects for large energy demands and how to support them with concentrated solar energy, including in Central Europe.

3.4.2.2 The German hydrogen strategy is a key driver for new technology investments

The launch in June 2020 of a National Hydrogen Strategy set the frame for German's priorities in terms of technologies. The funding programmes are looking for projects EU-wide and worldwide that demonstrate synergies between sectors. This could open a window for STE, especially through cooperation mechanisms.

Via a participation in the construction of new CSP plants in southern Europe or the Southern EU Neighbourhood (*e.g.*, in Spain, Portugal, Morocco), Germany could secure hydrogen imports from these countries, in which a strong research cooperation e.g. with the Spanish Ciemat in Almeria or the Evora University in Portugal exist.

Within the EU, the Pentalateral Energy Forum, of which Germany is a member, already held discussions on the strategic role of hydrogen. In a joint declaration[60], the Ministers of Energy underlined two main elements:

- "the potential of hydrogen, particularly from renewable sources, for the decarbonisation of hard-to-abate sectors, such as in industry and in transport and to play a key role in an integrated future energy system in Europe based on sector coupling and the development of seasonal energy storage".
- "the need for a timely scale up of the production of hydrogen in Europe in a coordinated way, with focus on renewable hydrogen, to ensure safe, competitive, available and sustainable energy supply, while increasing European cooperation, such as through the 'Clean Hydrogen Alliance' in the recently announced European Industrial Strategy".

One of the proposed solutions by the group is the development of concepts for cooperation, including:

- The identification of cross-border projects between Penta countries.
- The identification of and action on unnecessary regulatory and market barriers.
- The exploration of potential joint funding mechanisms.

3.4.3 Integrated findings

3.4.3.1 Structural dependence for relaunching STE

- The STE sector is one of the "less deployed" renewable technologies in Europe.
- In absence of a proper market following the installation with substantial participation of German R&I and industry of 2,3 GW CSP plants in Spain, the resurgence of this technology in Europe depends today on the engagement of the German industry, backed by the R&I sector and nurtured by global investors' appetite.
- This higher engagement is itself structurally dependent on:
  - Overall policy targets (as given by the "Klimaschutzgesetz" in Germany) that must be translated into project opportunities for STE technologies for electricity, process heat and fuels production also outside of Germany.
  - The setup of efficient policy/regulatory conditions to be finetuned in close contact with all layers of the German industry (utilities, manufacturers, service providers, SMEs) to allow the emergence of STE using projects at various industrial scales also considering the import of dispatchable electricity and green fuels.
  - The generation of a national home market for process heat application that have the potential to be decarbonised by STE technology also in Germany. However, as STE is not yet competitive in the market with technologies that are already established, a technology-open competition is premature. Measures

[60] *See https://www.benelux.int/files/1615/9077/7640/jointpoliticaldeclaration.pdf*

  that facilitate the market entry should be added, such as the support of project development and demonstration and pilot projects for STE process heat application also in Germany.
  - The continued support to publicly funded R&I activities (especially on high TRL level) cooperating with or aligned on the business potential of a.m. industry.
- The combination of the a.m. features was and remains one of the key building blocks elements to continue the German industrial success on STE world markets.

3.4.3.2 Exemplary coherence between public R&I funding and industry

- A good coherence exists in Germany between the support to R&I in STE (both in terms of research lines and the corresponding stable funding programs) and the energy policy ambitions of the country.
- In this context, the support to R&I activities in STE should be continued and even increased regarding STE applications for electricity, heat and fuels.
- This should include funding of project development activities, and project related feasibility studies as well as STE technology demonstration for the industry decarbonisation and solar fuels also outside of Germany.
- A more intense use of existing interfaces between industry, R&I and BMWi provided by various associations at national level that can then be relayed at EU level.

3.4.3.3 Cooperation on STE still a key to more business

- Since Germany further embeds its energy policy in a wider European context, the involvement of German companies in other European countries with abundant solar resources appears still as an opportunity to relaunch cooperation mechanisms for STE with shared benefits for participating countries. This does not hold for electricity only but also for green hydrogen and other solar fuels.
- In this regard, German legislation (Electricity bill) is well aligned with the cooperation mechanisms to be maintained in EU RES DIR 2021. This should be extended to green hydrogen production.
- Also the recent launch of the Renewable Energy Financing Mechanism (REFM) and other funding Elements (Carbon Contracts for Difference, Softloans) could play an important role in unlocking potential financing for cross-border commercial projects.
- The cooperation for the STE sector might also be increased via new initiatives between industry associations across borders, that could better combine their respective support towards the respective authorities relevant to specific international projects or specific uses of the technologies. The cooperation for the STE sector might also be increased via new initiatives between industry associations across borders, that could better combine their respective support towards the respective authorities relevant to specific international projects or specific uses of the technologies.

3.4.3.4 A timing issue and a causality dilemma

- The use of STE for the purpose of adding flexibility to the German electricity system is not perceived as urgent issue by the German system operators and the owners of current system generation infrastructures. However, the use of STE technology or related power-to-heat-to power technologies (using thermal storage) is not excluded as potential instrument for TSOs to mitigate grid operation challenges due to the expected substantial increase of variable RES in Germany's system. Keeping an involvement in STE technology for electricity would ensure for Germany that any future support to grid operation could be achieved at best costs and using German technology.
- Conversely, the German hydrogen strategy appears as expression part of a national system integration strategy as main driver of German energy policy.
- This hydrogen strategy – even if not yet mentioning STE as a vehicle to its implementation – feeds expectations from authorities about the possible contribution of STE in the production of green hydrogen to be imported form sun-rich areas.
- In this context, authorities and stakeholders should solve an *apparent* causality dilemma: while the political authorities call the industry to demonstrate the viability and the competitiveness of extended uses of STE for the national energy policy strategy, the industry calls authorities on supporting mechanisms especially for capital-intensive projects in worldwide markets.

3.5 Aligned conclusions and recommendations

- Focus on mechanism that facilitates the transition from the R&I phase to market entry of innovative technologies and applications for STE technologies. This should include:
  - the support of international project development.
  - extended funding schemes for demonstration combined different elements like REFM, KfW Soft loans, Carbon Contracts for difference, etc.
  - the generation of a home market for STE Process heat application.
  - elements of energy import like the EU cooperation mechanism that should allow extended to fuels green fuels production.

3.6 Glossary

BMU	German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety
BMWi	German Federal Ministry for Economic Affairs and Energy
CSP	Concentrated Solar Power
DNI	Direct Normal Irradiation
Deutsche CSP	German CSP association
EC	European Commission
EEG	Germany's Renewable Energy Act
ENTSO-E	European Network of Transmission System Operators
EU	European Union
GW	Giga Watt
H2020	Horizon 2020
IKI	International Climate Initiative in Germany
IP	Implementation Plan
KfW	KfW Development Bank
kWh	Kilo Watt hour
MW	Mega Watt
MW_e	Mega Watt of electricity
NECP	National Energy and Climate plan
ODA	Official Development Assistance
PJ	Peta Joule
PoF	Programme-oriented funding
PV	Photovoltaic
R&D	Research and Development
R&I	Research and Innovation
REFM	Renewable Energy Financing Mechanism
RES	Renewable Energy Sources
SET Plan	Strategic Energy Technology Plan
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TSO	Transmission System Operator

3.7 Appendices

3.7.1 References

Germany – R&I

BMWi, "7th Energy Research Programme" [online]

Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU), "International Climate Initiative (IKI) projects" [online]

Helmholtz Association, "Program-Oriented Funding (PoF)" [online]

Germany – Industry

AG Energiebilanzen e.V. website [online]

Bundesnetzagentur, "Bundesnetzagentur approves network development plan 2019-2030", 20 December 2019, Bundesnetzagentur website [online]

Clean Energy Wire, "What's new in Germany's Renewable Energy Act 2021", 6 Jan. 2021 [online]

Energy Transition, 15 May 2019 [online]

ENTSO-E, "Multi-sectorial planning support Roadmap by ENTSO-E", 16 July 2020, ENTSO-E website [online]

Federal Ministry for Economic Affairs and Energy, German National Energy and Climate Plan, European Commission website [online]

Federal Ministry for Economic Affairs and Energy, National Hydrogen Strategy, June 2020, Federal Ministry for Economic Affairs and Energy website [online]

Fraunhofer ISE, "Public Net Electricity Generation in Germany 2019: Share from Renewables Exceeds Fossil Fuels", 15 January 2020, Fraunhofer ISE website [online]

Pentalateral Energy Forum, Joint political declaration on the role of hydrogen to decarbonise the energy system in Europe, Pentalateral Energy Forum website [online]

3.7.2 Meeting guidelines

See APPENDIX.

3.7.3 Interview guidelines

See APPENDIX.

4 Chapter 4: Spain

4.1 Structure of the document

The "Integrated Country Report – Spain" aims to provide a global and structured approach of the country's profile regarding potential interest in STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2 and WP3 concerning:

- The expressed need for manageable renewable energy sources (RES) energy by the country of focus and the strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.
- The construction of a defined framework for funding and its reception by relevant audiences.
- The evaluation of performance of the funding frameworks.

Section 4.2 summarises the tasks which were carried out, both on the R&I (4.2.1) and industrial (4.2.2) sides. This gives an overview of the intelligence collected and of the key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Proposition of a reshaped funding framework based on feedback from stakeholders and the IWG.
- Dissemination of information about the funding opportunities and impact evaluation.
- Meeting with relevant stakeholders, i.e. at Ministry, Transmission System Operators (TSO) and Regulatory Authority levels, as well as key players from local industries and civil society.
- Joint industry-R&I national events.

A deeper analysis of the context of each country is provided in section 4.3, first for the research section (4.3.1) and then for the industry (4.3.2). Each of these sections provides a global overview of the different factors influencing the development of funding and commercialisation of STE applications. More precisely, it aims to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Spain.

Based on these observations, key findings are drawn in section 4.4, for both research and industry. They highlight encountered challenges and existing opportunities and finally draws a picture of the potential synergies between R&I and industry structures.

Last but not least, section 4.5 suggests strategic actions to continue opening doors for STE in Spain, from a research and industrial point of view. It finally offers an overarching approach to further support the development of STE in Spain, combining R&I and industry perspectives to offer thorough advice.

4.2 Summary of undertaken activities

Spain has been under the scope of analysis from October 2019 until April 2022. The Covid-19 global pandemic has slowed down the process. A close cooperation has been implemented between ESTELA and CIEMAT, and the consortium also received a strong support from the Spanish CSP association, Protermosolar, to maximise impacts and meaningful results.

The following chapters will describe the work undertaken in Spain and analyse the challenges and opportunities met in the country.

4.2.1 R&I methodology

To have a wide overview of the R&I landscape of Spain the following activities were carried out:

List of activities	Timeline
Stakeholders Survey	Phase 1 Oct. 2019 – Jan. 2020
Aim: Determine the interest and capabilities of Spanish (and other European) stakeholders for the realisation of projects directly related to the SET-IP activities.	
Description:	8 R&I topics of the SET-IP plus first-of-a-kind demonstration projects were subdivided into systems and components; potential research activities were proposed. The survey participants selected their area of competence and provided comments about the funding framework. The outcome of this exercise was provided to the consortium CSP-ERANET in order to shape the upcoming calls according to the capabilities and interests of the stakeholders.
Background research	Phase 1 Sept. 2020 – Mar. 2022
Aim: To identify ongoing R&I activities, funding sources, existing infrastructure, legal framework and stakeholders.	
Description Desk research:	Revision of the SET-IP and identification of possible updates or revisions. Update of list of projects being carried-out with participation of industrial and/or research partners. Revision of the national funding framework. Revision of energy policies that affect the scope of research activities.
Brokerage event	Phase 2 May 2021 – Mar. 2022
Aim: To have a broad overview of STE activities and plans in Spain from the R&I. To be held together with the industrial event, as the participation of the industry on research activities is crucial in Spain.	
Description A series of online meetings with national stakeholders were held as a mitigation measure due to the COVID-19 pandemic restrictions.	
National event	Phase 3 July 2022

List of activities	Timeline
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations in order to fulfil the SET-IP. To be held together with the industrial event, as the participation of the industry on research activities is crucial in Spain.	
Description The joint industry and R&I national event took place on 06 July 2022 at CIEMAT premises, Madrid, Spain. The main conclusions and highlights of the event will be reported in the Deliverable 4.7 "Proceedings of the Joint Industry and R&I Events".	

4.2.2 Industry

4.2.2.1 Foreseen activities and implementation challenges

To favour a sustainable launch of STE in studied countries, ESTELA designed a general process unfolding in three steps with flexibility to adapt to specific country challenges:

PHASE 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and Spain's strategies for the development of RES in the country and for import / possible changes in the relevant framework conditions
Encountered challenges	– To find the right interlocutor – Low answer rate to interview requests – Mixed information received from different interlocutors
Applied mitigation	– Help from CIEMAT, Protermosolar, and the IWG Chair to identify relevant stakeholders – Send two reminders when facing unanswered requests – General translation of official documents from Spanish to English – Confrontation of different sources with the official source
PHASE 2	
BROKERAGE EVENT	
General aim	Assessment and presentation of potential solutions using CSP/STE
Encountered challenges	– Covid-19 global pandemic – Delay of the CSP auction in 2022
Applied mitigation	– Focus on the crucial design aspects of the expected CSP auction instead of its results – Promoting cross-border projects opportunities
PHASE 3	
JOINT NATIONAL EVENT	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	– Outbreak of covid-19 global pandemic – Not enough data collected yet
Applied mitigation	– Awaiting the end of the pandemic to evaluate the possibilities

4.2.2.2 Carried out activities

LIST OF ACTIVITIES		TIMELINE
BACKGROUND RESEARCH		Phase 1 Nov. 20-June 21
Aim: To collect relevant information to better understand the energy landscape in Spain, the potential challenges for the development of STE and the needs of the country		
Description		
Desk research:	Collect of information based on available information on official websites (Institute for Diversification and Saving of Energy (IDEA), Red Eléctrica de España (REE), Ministry for the Ecological Transition and the Demographic Challenge (MITECO), European Commission, etc.), academic studies or reports by consultancies	
Stakeholder mapping:	Analysis of the specific relevant departments and actors for each identified target group Exchanges with Protermosolar on relevant contacts and existing knowledge of the local situation	
PRELIMINARY TALKS		Phase 1 Jan.-Mar. 2020
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable RES, the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions		
Description Ideally, this phase aims to establish a first physical contact with the three key stakeholders in Spain regarding energy policy, namely the TSOs, the Ministry and the Regulatory Authority. However, as the Covid-19 pandemic forced EU borders to be closed and travels to be restricted, HORIZON-STE could not organise these meetings and had to hold them online		
Regulatory Authority:	Interview with representatives of the regional Government of Extremadura & Extremadura Energy Agency (AGENEX) Interview with representatives of the Regional Government of Castile-La Mancha Interview with representatives of the Regional Government of Andalusia/Andalusian Energy Agency	
PHONE INTERVIEWS		Phase 1 May 2021 – Mar. 2022
Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of Spain's energy strategy and potential need for manageable RES		
Description		
Ministry	Interview with representatives of MITECO	
Regulatory Authority:	Interview with representative of IDAE	
Protermosolar:	Interview with a representative of Protermosolar, also Board Member of ESTELA	
BROKERAGE EVENT		Phase 2 May 2021 – Mar. 2022
Aim: To have a broad overview of STE perspectives in Spain through existing and potential solutions using STE, from both the R&I and industry sides.		

LIST OF ACTIVITIES	TIMELINE
<u>Description</u> A series of online meetings with national stakeholders were held as a mitigation measure due to the COVID-19 pandemic restrictions.	
NATIONAL EVENT	Phase 3 July 2022
<u>Aim:</u> To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the support of Spanish STE industries involved in foreign STE projects and concentrated solar thermal technologies for industrial heat. To focus on possible synergies and macro-economic value.	
<u>Description</u> The joint industry and R&I national event took place on 06 July 2022 at CIEMAT premises, Madrid, Spain. The main conclusions and highlights of the event will be reported in the Deliverable 4.7 “Proceedings of the Joint Industry and R&I Events”.	

4.3 Overview of the context in Spain

4.3.1 R&I landscape

This section presents the main outcome of the background research and the analysis of the information and opinions collected from Spanish R&I entities involved in CST technologies. It is divided into the financial framework, research infrastructures, R&I entities and the list of R&I projects. CIEMAT has provided substantial input to describe thoroughly the context of the R&I landscape in Spain.

4.3.1.1 Funding opportunities for R&I activities in Spain related to CST technologies

The "State Scientific, Technical and Innovation Research Plan 2021-2023 (PEICTI)" defines the main framework for the R&I policy and related funding in Spain. The PEICTI is composed of four programmes and 13 subprogrammes. At national level, there are two main public entities in Spain financing R&I projects related to CST: the Centre for Industrial Technological Development (CDTI) and the State Research Agency (AEI), both managed by the Spanish Ministry of Science and Innovation (MCIN).

The CDTI has multiple instruments to fund the R&I projects of the Spanish industry. The funding mainly contains grants and soft loans in an open, rather than competitive call with possibility to obtain a funding of several million euros. The CDTI doesn't have dedicated budget for each energy sector and Spanish entities, other than industry, must participate as subcontracted entities in the projects funded by the CDTI. R&I funds distributed by the CDTI are not only provided by the Spanish Government, but also by the European structural and investment funds and the European Investment Bank. Although most of the CDTI funding programmes are for R&I activities, there are also funding programmes for innovation and expansion. CST is one of the eligible sectors to get the CDTI financial support within these funding programmes. Within the set of the CDTI funding programmes suitable for CST R&I projects there are three programmes with special requirements and characteristics - the CIEN, CERVERA and MISIONES.

The CIEN is a programme designed for large R&I projects offering funding in the range from 5 to 20 million euro and the duration of 3 to 4 years. The projects eligible for this funding programme are large industrial research and experimental development projects promoted by joint ventures and aimed at developing a research programme in strategic areas with potential international impact. Since this programme is also designed to enhance public-private partnership in R&I, it is compulsory the participation of research centres as subcontractors of the joint venture to undertake relevant activities in the project. Each project must be composed of a minimum of 3 and a maximum of 8 entities, with at least 1 SME.

The CERVERA programme is aimed at strengthening the capacities of R&I and technological Spanish centres to enhance their driving role in the Spanish Science, Technology and Innovation System. The objective pursued is an improvement of the capacities of Spanish R&I and technological centres and the improvement of the collaboration among them. Only those centres included in the official list of Spanish Technology Centres or Supporting Centres for Technology Innovation are eligible to receive funding from the CERVERA Programme.

The MISIONES funding programme focusses on large strategic R&I initiatives aims at identifying and solving the challenges of critical productive sectors for the Spanish economy. Projects submitted to this programme are promoted by joint ventures of more than three industrial partners, which must subcontract at least 15% of the total budget to research centres. The eligible budget per project must be in the range from 5 to 10 million euro (projects submitted by large enterprises) or in the range from 1.5 to 3 million euro (projects submitted by SMEs). This funding programme is especially suitable for large R&I industrial initiatives related to CSP.

The AEI also supports R&I projects in Spain mainly through competitive calls for consortia including Spanish companies and research organisations. The goal of these funds is to promote the development of new technologies and the business application of new ideas and techniques. There is not a dedicated budget per sector and CST projects must compete with the rest of technologies in the competitive calls launched by the AEI. The funding support is usually composed of grants and soft loans.

The AEI manages three funding programmes for R&I, one of which is rather suitable for projects related to CST - "*State programme to promote scientific-technical research and its transfer*" – and is composed of four subprogrammes:

– "State subprogramme for the generation of knowledge".
– "State subprogramme for knowledge transfer".
– "State institutional strengthening subprogramme".
– "State subprogramme for infrastructures and scientific-technical equipment".

The most suitable subprogramme for CST R&I projects is the "*State subprogramme for the generation of knowledge*", which provides funds for four different types of projects:

– Knowledge generation projects.
– R&I projects on health issues.
– Strategic projects (ecological and digital transition projects or projects on the strategic lines defined in the yearly actuation programmes).
– Research networks.

R&I projects on CST usually match the requirements defined for project type *Knowledge generation projects* or the *Strategic projects*, and therefore receive funds from the "*State subprogramme for the generation of knowledge*", usually via yearly calls. The nature, beneficiaries and requirements depend on the type of project.

The beneficiaries of the funding provided to the project type K*nowledge generation projects* may be public research organisations, universities, research centres, technology centres, research institutes, and R&I institutions. Thus, it covers two types of projects, with a duration of 2 to 4 years:

– Non-oriented research projects, without previously defined thematic orientation, which are motivated by scientific-technical curiosity and whose primary objective is to advance knowledge regardless of the time horizon and its scope of application.
– Research projects aimed at solving specific problems and linked to the great challenges of society, which are included in some thematic priorities established in

the PEICTI: health, culture, creativity and inclusive society, civil security for society, digital world, industry, space and defence, climate, energy and mobility, food, bioeconomy, natural resources, and the environment. Other areas will not be excluded as long as they contribute to achieving the objectives of said PEICTI.

Ecological and digital transition projects, available for universities, public R&I centres, technological centres and public or private entities, may include any of the following topics:

- Energy decarbonisation.
- Energy efficiency.
- Renewable energies deployment.
- Economy electrification.
- Energy storage.
- Circular economy.
- Resiliency improvement of all the economy sectors.

The subprogramme "*State subprogramme for knowledge transfer"* also provides funding for R&I activities related to CST. It includes several project categories, including:

- Projects for proof of concept.
- Public-private partnership projects.

The minimum budget for these projects is 400,000 euro with a duration of 36 months. Beneficiaries must be public-private partnerships coordinated by a private company.

CDTI and AEI are participating in CSP Solar ERANET programme as one instrument for cross-national funding. International (EU and associated countries) cooperation projects can also be funded through the multilateral programmes (EUREKA, IBEROEKA, Bilateral programmes, EUROSTARS, etc.), however, no specific funding for CST R&I activities is available and projects related to different technologies must compete each with others for the funding.

At present, the CSP ERANET[61] is managing a common fund given by the funding agencies of several Member States, Associated Countries and Regions to achieve IP CSP SET Plan objectives, by pooling their financial resources to implement joint calls for R&I proposals, resulting on strategic projects with substantial volumes of investment, which cannot be allocated by individual countries or by the EC on their own. The first Call of CSP Solar ERANET was issued in October 2019, while the second call was issued late in 2021. However, the CSP Solar ERANET scheme will be no longer used after the Framework Programme Horizon 2020, because it has been replaced in the Framework Programme Horizon Europe by a new funding scheme called "*Partnerships*" which will foster joint actions between Horizon Europe EU programme and national funding programmes on common R&I priorities, building on – and bringing forward – the work carried out in the SET-Plan. With regard to the CST topic, the relevant initiative is the "*Clean Energy Transition Partnership*".

[61] *See https://csp-eranet.eu/*

EUROSTARS[62] is a European Joint Programme (EJP) specially dedicated to the R&I performed by European SMEs, and co-funded by the EC and the participating countries. Programme aims to stimulate SMEs to lead international collaborative research and innovation projects by easing access to support and funding. It is fine-tuned to focus on the needs of SMEs, and specifically targets the development of new products, processes and services and the access to transnational and international markets.

The programme has a central submission and evaluation process and synchronised national funding in all the participating countries. EUROSTARS projects are collaborative - they must involve at least two participants (legal entities) from two different EUROSTARS participating countries. In addition, the main participant must be a research-performing SME from one of these countries.

Although EUREKA programme in Spain is useful for the industrial partners because of the level of funding available, this programme is not very appealing for Spanish R&I entities, as only marginal cost can be funded, thus reducing their usefulness to promote CST related research. Another disadvantage of this and CSP Solar ERANET programme is the lack of a unified time schedule for the calls at European and national levels. The duration of the funding period and the funding intensity for R&I entities are additional disadvantages in CSP Solar ERANET projects because the financing of projects is up to 36 months only and the maximum amount of funding is usually less than 400,000 euro per project. So, Spain should strive to make these programmes more appealing for Spanish R&I entities and to define a common time schedule for all the countries.

EJP co-fund is another action designed to support coordinated national R&I programmes at European level. Unfortunately, at the moment the suitability of EJP co-fund for CST R&I activities isn't clear, as there is no EJP co-fund for CST and participating entities so far have only been research funders or governmental research organisations. In addition, EJP co-fund initiatives require high level of commitment and co-funding from government ministries and organisations, which seems very difficult to be achieved around CST.

4.3.1.2 Existing R&I activities

Spain is the world leader in the number of the STE plants (50) and also in the total power installed (2,3 GWe). This leadership has enhanced the collaboration between the industrial and R&I sectors, thus promoting a high number of research projects aimed at making STE plants more competitive with conventional ones by either improving the technology or reducing costs.

The 50 STE plants installed in Spain between 2007 and 2013 have been an excellent background for R&I. Due to the need for cost reduction and technology improvement the number of Spanish research groups working on CST technologies and their applications has been growing during the last 15 years, thus providing the industrial sector with an excellent scientific support.

Table 21 shows the list of national and European projects related to CST technologies. Only projects ending in 2020 or later have been included, it clearly depicts the high R&I effort devoted by Spanish entities to the development of CST technologies. Industry in Spain has long standing R&I tradition in CSP research, dating back to mid-2000s, when country

[62] *See https://www.eurekanetwork.org/countries/spain/eurostars/*

was the leading force in the CSP industry. The key data of these projects is shown in Table 20 below.

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
EU	Dispatchable renewable energy sources for a modern power system mode	POSYTYF	Centrale Nantes	2020-2023	Iberdrola Generación	CIEMAT, Univ. Politécnica de Cataluña, Univ. Católica de Comillas
EU	Competitive Solar Power Towers	CAPTURE	CENER	2015-2020	---	CENER, CIEMAT, TEKNIKER
EU	High performance parabolic trough collector and innovative silicone fluid for CSP power plants	Si-Co	ACCIONA	2021-2023	ACCIONA, RIOGLASS, TEWER	CIEMAT
EU	Advanced materials solutions for next generation high efficiency concentrated solar power (CSP) tower systems	NEXTOWER	ENEA	2017-2021	UNE, R2M Solution	CIEMAT, ICAMCYL, ICCRAM
EU	Solving Water Issues for CSP Plants	SOLWARIS	TSK Electrónica y Electricidad	2018-2022	TSK Electrónica y Seguridad, RIOGLASS, Ingeniería para el Desarrollo	CIEMAT, TEKNIKER, Barcelona Supercomputing Centre

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
					Tecnológico, FENIKS Cleaning&Safety	
EU	Solar Facilities for the European Research Area	SFERA-III	CIEMAT	2019-2022	---	CIEMAT, IMDEA, Univ. Almería
EU	Integrating National Research Agendas on Solar Heat for Industrial Processes	INSHIP	Fraunhofer	2017-2020	---	CIEMAT, CENER, IMDEA, CTAER, TECNALIA, TEKNIKER, CIC-Energigune, IMDEA
EU	Raising the Lifetime of Functional Materials for Concentrated Solar Power Technology	RAISELIFE	DLR	2016-2020	---	CIEMAT, Univ. Complutense de Madrid, Instituto Técnica Aeroespacial
N	Soluciones termosolares para integración en procesos industriales	SOLTERMIN	CIEMAT	2018-2021	---	CIEMAT
N	Energía solar Térmica de	ACES2030	IMDEA-Energy	2019-2022	---	CIEMAT, IMDEA-Energy

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
	concentración en el sector del transporte y en la producción de calor y de electricidad					
EU	HYDROgen production in a SOLar structured reactor:facing the challenges and beyond	HYDROSOL Beyond	APTL	2019-2022	ABENGOA	CIEMAT
N	Energy Storage solutions based on concrete	E-CRETE	CFM-CSIC	2019-2022	---	CIEMAT, Centro de Física de Materiales (CSIC-UPV/EHU, TECNALIA, CSIC, Donostia International Physics Center (DIPC)
N	PV Plant with thermal CoGeneration	SOLARBLUE	Magtel	2019-2021	MAGTEL	CIEMAT
N	Recubrimientos solares de alta eficiencia	HiPimSOLAR	Univ. Sevilla	2020-2022	---	CIEMAT, Univ. Sevilla

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
EU	MOdular high concentration SolAr Configuration	MOSAIC	TEKNIKER	2016-2021	ACS-COBRA, RIOGLASS, INCRESCENDO	TEKNIKER, CENER
EU	Advanced Materials technologies to QUADRUPLE the Concentrated Solar Thermal current POWER GENERATION	IN-POWER	Acondicionamiento Tarrasense Associacion	2017-2020	LEITAT, NEMATIA, FERTIBERIA, MAGTEL	TEKNIKER
N	Desarrollo de Actividades de Investigación Fundamental Estartégica en Almacenamiento de Energía Electroquímica y Térmica	CICe15-20	CIC-Energigune	2015-2021	---	CIC-ENERGIGUNE, TEKNIKER
N	Development of high temperature and low cost advanced thermal storage systems	HTSTORAGE	CENER	2017-2019	---	CENER

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
N	Captador solar innovador para calor de proceso con aplicación de recubrimientos selectivos como ventaja competitiva (COSmIC).	COSMIC	CENER	2019-2020	Asociación de la Industria Navarra (AIN)	CENER
EU	High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage	NEXT-CSP	CNRS	2016-2021	---	IMDEA
N	Multidisciplinary analysis of indirectly-heated particles receivers/reactors for solar applications in extreme conditions	ARROPAR-CEX	IMDEA	2016-2020	---	CIEMAT, IMDEA
EU	SOlar Calcium-looping	SOCRATCES	Univ. Sevilla	2018-2021	ATRIA Smart Energy Solutions,	Univ. Sevilla, Univ. Zaragoza, CSIC

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
	integRAtion for Thermo-Chemical Energy Storage				BIOAZUL S.L., VIRTUALMECHANICS S.L.	
N	Algoritmos numéricos avanzados para la mejora de la eficiencia energética en los sectores eólico y solar-termico: Desarrollo/adaptación a nuevas arquitecturas computacionales	ANUMESOL	Univ. Politécnica Cataluña	2018-2021	---	Univ. Politécnica Cataluña
N	Polyol-based latent TES systems with controlled discharge	Sweet-TES	CIC energiGUNE	2019-2021	---	CIC energiGUNE

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
EU/N	Fomento de tecnologías innovadoras para la mejora de la eficiencia en el proceso de secado de los lodos de Aguas Residuales y de secado de Residuos Sólidos Urbanos mediante el uso de Tecnologías Solares en Andalucía-Algarve-Alentejo	SECASOL	Dip. Huelva	2017-2020	CEPSA Gestión de Residuos	Dip. Huelva, Centro Nuevas Tecnologías del Agua
EU	Application of Solar Thermal Energy to Processes	ASTEP	UNED	2020-2024	---	UNED, UPM, Dynamic&Security Computing, Univ. Ppolitécnica Cartagena, Univ. Politécnica Madrid, Iris Technology

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
EU	Techno-economical evaluation of different thermal energy storage concepts for CSP plants	CSP-Plus	University of Lleida - GREiA	2021-2024	ABENGOA	Univ. Lleida, Univ. Barcelona
N	Methodology for the analysis of TES technologies towards a circular economy	MATCE	University of Lleida - GREiA	2019-2022	---	Univ. Lleida
EU	Integrated Catalytic Recycling of Plastic Residues Into Added-Value Chemicals	i-CAREPLAST	CSIC	2018-2022	KERIONICS S.L., URBASER	CSIC, Univ. Poliécnica Valencia
EU	Components´ and Materials´ Performance for Advanced Solar Supercritical CO2 Power Plants	COMPASsCO2	DLR	2020-2024	SUGIMAT S.L.	CIEMAT

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Spanish Industrial Partners	Spanish R&I Partners
EU	Small-Scale Solar Thermal Combined Cycle	POLYPHEM	CNRS	2018-2022	ARRAELA S.L.	CIEMAT
EU	Implementation of the Initiative for Global Leadership in Solar Thermal Electricity	HORIZON-STE	ESTELA	2019-2022	---	CIEMAT

Table 21: R&I Projects with involvement of Spain since 2015 relevant to the SET IP

The strong collaboration between the CST industrial sector and the Spanish R&I groups is clearly depicted by the high number of research projects that have been developed or are still underway with the participation of universities, technological and research centres. At present, there are more than 10 Spanish universities with important R&I groups, which produce a high number of scientific papers and doctoral thesis every year.

Research activities currently performed by Spanish entities (industrial partners, R&I centres, universities and technological centres, mainly) cover a wide range of topics:

- Integration of CSP/STE plants with other renewable energy technologies.
- Innovative working fluids for line-focus concentrating solar systems.
- Components and materials for supercritical CO_2 power cycles.
- New concepts for CSP/STE plants (e.g. multi-tower approach).
- Advanced/innovative heliostat designs.
- New thermal energy storage (TES) systems using sensible heat, latent heat or thermochemical processes.
- Water saving technologies for CSP/STE plants.
- Better O&M strategies for commercial CSP/STE plants (e.g. integration of soiling forecast in the maintenance procedures of the plant).
- Testing and qualification protocols for components of CST plants.
- New parabolic-trough and linear Fresnel collector designs.
- Application of CST technologies for hydrogen production and thermochemical processes.
- On-line measurement of solar flux onto central receivers.
- Particle-receiver technology.
- New optical coatings (selective, anti-reflective and anti-soiling coatings).

It is expected that these projects will bring into the market a few technical improvements that will reduce either the environmental footprint of CSP plants (e.g. replacement of current diphenyl oxide/biphenyl oils by silicone-based oils) or the Solar Thermal Electricity Cost (LCOE). However, rather than expecting a single great impact on the LCOE, a number of small contributions that altogether could reduce the LCOE in the range of 20-25% are anticipated.

Although there are also interesting ideas that could lead to significant technology improvements, the Spanish partners proposing those innovations have been unable to get the public funding required for their development. A good example is the GAIA project, which was submitted to the H-2020 call LC-SC3-2020-RES-IA-CSA. Improvements proposed in GAIA for the central receiver and heliostat field could lead to a cost reduction of more than 10%. Although the project was awarded with a score of 13/15 and proposed for funding by the evaluators, the project was not funded by the EC because in that Call there was budget for only one proposal.

The unsuitability of national funding available for R&I centres is another significant barrier for the development of CST technology improvements in Spain. Funding offered by the AEI to R&I centres only covers marginal cost, not the cost of temporary manpower, which is a significant percentage of the total manpower cost in Spanish R&I centres due to the lack of permanent staff imposed by administrative restrictions. The availability of funds is not at the level required to develop all these ideas and proposals, thus jeopardising the development of the learning curve of CST technologies. This is proven by the fact that sometimes project proposals obtaining a high score during the evaluation process do not get funding due to the very limited amount of funding available.

Although the Spanish CDTI has funding programmes where R&I projects can get a high funding (i.e., several million euro) the number of proposals submitted to CDTI is high and there is not budget available for all of them. It has been already commented that the situation is even worse with European funding in the Framework Programmes because the EC has been reducing the funding devoted to CST technologies, while increasing the funding available for projects related to photovoltaic or wind technologies.

In Spain there are already excellent research facilities for CST technologies. The most outstanding research centre is the Plataforma Solar de Almeria (PSA)[63], which is formally recognised by the EC as a large European research facility. At national level, PSA is included in the small group of Unique Scientific and Technical Infrastructures devoted to energy, which includes only one more Spanish R&I facility.

Table 22 is a summary list of the main PSA facilities devoted to CST, while Figure 23 in an aerial view of one of the facilities. At PSA there are two experimental central receiver plants: the CESA-1 and the CRS plants, with a nominal thermal power of 6 MW and 2,5 MW at their focal point, respectively. The towers of these two systems are provided with several test levels at different heights, thus allowing several experiments in parallel. These tower plants have 300 and 91 heliostats, respectively.

Type of facility / laboratory	No. of Units	Facility Name
Central receiver	2	SSPS CRS CESA-1
Parabolic Trough	7	HTF test loop REPA DISS plant Innovative Fluids Test Loop TCP-100 PROTERMO KONTAS
Linear Fresnel	1	FRESDEMO
Furnace	3	SF-60 SF-5 SF-40

[63] *See www.psa.es*

Type of facility / laboratory	No. of Units	Facility Name
Solar Thermal Desalination	3	MED CSP+D MDTF
Solar Simulator	1	4kW – 7kW solar simulators
Molten-salt test facilities	3	BES-I BES-II Molten Salt Test Loop (MOSA)
Laboratories	8	Materials lab Solar Reflectors lab (OPAC) Geometrical Characterisation of Solar Concentrators lab Accelerated Ageing and Durability of Materials lab Radiometry lab Advanced Optical Coatings lab Porous Characterisation lab Solar hydrogen Evaluation lab

Table 22: List of the PSA facilities devoted to CST

Figure 23: Aerial view of the PSA facilities

There are also several large test facilities for parabolic trough collectors at the PSA, using different working fluids (i.e., thermal oil, water / steam or supercritical CO_2). The so-called PSA HTF Test Loop is devoted to the evaluation of components for parabolic trough collectors (e.g. mirrors, receiver tubes, flexible connections, sun tracking systems, etc..). The Parabolic Trough Test Loop facility has a balance of plant suitable to evaluate complete rows of parabolic trough collectors. At the Innovative Fluid Loop facility supercritical CO_2 is used as working fluid in a small solar field with parabolic trough collectors.

At the PSA there are also five parabolic dishes of 50 kW of thermal output each, and three solar furnaces with unit power of 60 kW, 40 kW and 5 kW, respectively. There is also a 2-tank molten salt thermal storage system (the so-called MOSA facility) and two test benches for evaluation and qualification of equipment for molten salt circuits.

In addition to the outdoor test facilities, PSA has outstanding indoor laboratories for advanced optical coatings, geometrical characterisation of solar concentrators, qualification of linear receiver tubes and characterisation of solar reflectors.

Due to all its outdoor experimental facilities and the indoor laboratories, the PSA is nowadays the largest public R&I centre devoted to CST technologies. The PSA test facilities are kept in good operating conditions thanks to the special funds provided by the Spanish Government for this specific purpose.

There are several more R&I centres in Spain with facilities and laboratories devoted to CST technologies. IMDEA[64] has an experimental central receiver plant in Madrid with small-size heliostats (see Figure 24), CIC-Energigune[65] has small test facilities and laboratories devoted to thermal storage topics, while CENER[66] has several laboratories for components characterisation.

Figure 24: Central receiver test facility of IMDEA Energía (courtesy IMDEA)

[64] *See https://www.energia.imdea.org*

[65] *See https://cicenergigune.com/en/thermal-storage-research*

[66] *See http://www.cener.com*

There are also technological centres with laboratories and facilities that can be used for CST R&I, although they are not only devoted to this field. TECNALIA[67] and TEKNIKER[68] are two of these Spanish technological centres. There also are outstanding indoor test facilities at several universities, like the molten-salt test bench available at the University Carlos III (Madrid) or the test facility existing at the University of Lleida. The Stirling dish facility at the University of Seville is also worth mentioning here. With the comprehensive set of R&I facilities available in Spain a significant support can be provided to most of the R&I activities related to CST technologies for both CSP plants and solar heat applications for industrial processes (the so-called "SHIP applications"). These facilities are an excellent support for the current leadership of Spain in this field.

The high quality of the existing facilities in Spain will be even improved by means of the European project SFERA-III. The round robin tests and the joint R&I activities performed by the Spanish SFERA-III partners in collaboration with partners from other countries will improve the test protocols and the quality standards applied not only in Spanish R&I facilities but also in other European facilities available for components characterisation and evaluation.

4.3.1.3 National and International Cooperation

Spanish stakeholders of the CSP sector have a strong and fruitful collaboration in R&I at both national and international levels. A good proof of this intense collaboration is the list of R&I projects shown in Table 21. Many additional project proposals have been promoted and submitted to national funding entities and the framework programmes of the EC, however, the lack of funding has made their development impossible.

Spain is member of SolarPACES[69], a technology collaborative programme of the International Energy Agency. SolarPACES has 18 member countries: Australia, Austria, China, European Commission (DG RESEARCH & INNOVATION and DG ENERGY), France, Germany, Greece, Israel, Italy, Mexico, Morocco, Namibia, Republic of Korea, South Africa, Spain, Switzerland, United Arab Emirates and United States of America. This programme is the leading international network of researchers in thermal solar for dispatchable power and solar chemistry technologies. Activities performed within SolarPACES are aimed at achieving a significant contribution of the CST technologies to the delivery of clean, sustainable energy worldwide. This objective is pursued by means of the international researchers and thermal solar industry experts conducting research. Spain is currently coordinating the working group about *Reflectance Measurements* within Task III of SolarPACES, integrated by 11 R&I centres and companies, and participating in all the other Tasks of programme.

Spanish R&I stakeholders are also playing a significant role within the EJP CSP of EERA[70], which is coordinated by a Spanish researcher of the PSA. This EJP currently involves 15 full participants plus 11 associated participants. Five out of the 15 full participants are from

[67] *See https://www.tecnalia.com/es/energia-medioambiente/index.htm*

[68] *See https://www.tekniker.es/es*

[69] *See https://www.solarpaces.org/*

[70] *See https://www.eera-set.eu/*

Spain, while three out of the 11 associated participants are also Spanish. These number clearly depict the great involvement of Spanish R&I stakeholder in this EJP.

The involvement of Spanish R&I stakeholders is also very significant in the international standardisation committee IEC/TC117 "Solar Thermal Electric Plants". Spain is undertaking the Secretariat of this standardisation technical committee and many Spanish entities from the industry and the R&I sectors are involved in the development of the six new standards promoted by IEC/TC117 related to CSP plants. The standardisation effort at national level is developed within the Spanish AEN/CTN 206/SC117 of AENOR.

There is also an outstanding international collaboration with foreign universities and R&I centres, not only from other European Countries (Engicer, Haver and Boecker, ENEA, CNRS, LNEG, DLR, METU, Fraunhofer ISE, CYI, Univ Evora, Univ of Cranfield, Politechnico of Milano, Tech. University of Denmark, Soltigua; Zettl, Flabeg, Alanod and Almeco, AREVA, Liqtech International, InPhoTech, AGC, Huiyin Group, TG-Yueda, Sunnpo, Sundhy, and many others), but also from American countries (e.g. Universidad Católica de Chile and Universdad de Antofagasta (Chile), Universidad del Norte (Colombia), Universities of Sao Paulo and Federal de Pernambuco (Brasil), Universidad de La Plata (Argentina), Universidades Nacional Autónoma de México y Autónoma del Estado de México (México) and many others).

Spanish R&I entities are participating in the Solar Heating & Cooling tasks of the International Energy agency. An example is the Task 64 of Solar Heating & Cooling and Task IV of SolarPACES, where Spain is leading the Subtask B devoted to "Modularisation".

At EC level, the current and strong involvement in the CSP IWG (leaded by Spain through the MCIN) of SET-Plan and within the Clean Energy Transition Partnership provides Spain a unique position of visibility, influence and lobbying possibilities.

Finally, the EU-SOLARIS initiative, a distributed ESFRI organisation having at PSA its main central node, will be another important element of international relevance of Spain in the field of CST technologies within the coming years. This organisation, formally to be created and hosted within the PSA, will strongly promote and facilitate further collaboration among Europe and especially with German, French, Portuguese, Turkish, Cypriots, Greek and Italian R&I and industrial organisations. EU-SOLARIS will formally start its activities in 2022.

4.3.1.4 Existing active networks

Protermosolar[71] is the Spanish national association for the promotion of the thermo-solar industry. Association is very active in the promotion of CSP and is in close contact with the industrial sector, R&I centres and Spanish Administration. With 43 members and 11 collaborators, association is the reference entity in Spain for the sector. They participate in most of the national dissemination events related to CST technologies and applications. The association also provides guidelines to the authorities to promote CSP technologies and is the focal contact point of the Spanish industrial sector involved in CSP. The following items are included in the objectives of Protermosolar concerning CSP plants and technologies:

[71] *See https://www.protermosolar.com*

- Promotion of CSP plants within a stable and suitable legal framework.
- Enhance the technical development of CST technologies, collaborating with the national and regional governments in the definition of supporting measures and facilitating the collaboration with the R&I centres.
- Improvement of the operation and maintenance of CSP plants.
- Dissemination of CST technologies and their great commercial potential, together with their benefits for the society at large and the climate change.
- Protection of the interest of the industrial Spanish sector.

Another Spanish network in the CSP field is SOLARCONCENTRA[72], which is supported by the Spanish government. SOLACONCENTRA is an active forum in which the members represent the whole value chain of the Spanish CSP sector. Among the members there are public institutions, technological centres, companies, associations, technological platforms and researchers. There are two working groups implemented in SOLARCONCENTRA:

- Working group on CST. This group analyse the evolution of the CSP sector and the performance of the commercial plants already in operation.
- Working group on medium temperature. This group is focussed on solar process heat applications and their promotion and development.

SOLARCONCENTRA has been continuously growing since its launching and it had 157 members at the end of 2021.

A rather more modest network in Spain in the field of CST technologies is the Network SOLTERCO, launched in January 2020 with the support of the Spanish government for a period of three years (expiring in December 2022). All members of SOLTERCO belong to the R&I sector: CIC-ENERGIGUNE, CIEMAT, CENER, IMDEA Energía, TEKNIKER, University of Carlos III (Madrid), University of Seville and Polytechnic University of Catalonia. The goal of this network is to promote the use of concentrating solar thermal technologies. This objective is fulfilled with the participation of the members in international working groups and associations (e.g. SolarPACES, EU-SOLARIS, IEC-TC117 standardisation international committee, AEN CTN206 SC117 standardisation Spanish committee, EERA EJP for CSP) and the organisation/participation in dissemination events. SOLTERCO is included in the group of Spanish Strategic Networks.

4.3.1.5 Financing frameworks

As explained in section 4.3.1.1, there are two funding entities at national level for R&I projects on CSP: the CDTI and the AEI, both managed by the MCIN. Funding from CDTI is more suitable for the industrial sector, while that provided by the AEI is more suited for R&I entities. However, neither of these two entities have specific programmes for R&I projects for CSP and these projects must compete with other technologies in the common calls issued by these funding entities. Due to the many ideas and project proposals submitted by Spanish stakeholders for efficiency increase or / and cost reduction to these two funding entities, the funding available can't cover most of the

[72] *See http://www.solarconcentra.org/*

proposals. So, in Spain there is not a lack of innovative ideas, but a lack of funding. The same happen at European level with the Framework Programmes launched by the EC. At regional level, most of the regional governments have funding programmes to promote R&I activities in renewable energies. However, the regional programmes provide a small amount of funding, which is mainly aimed at university R&I groups, regional R&I entities and local companies.

4.3.2 Overview of the context for industry

The desk research and the preliminary interviews helped ESTELA refine its understanding of the energy context in Spain. The following subsections were enriched thanks to ESTELA's own desk research and inputs from the following stakeholders: Protermosolar, MITECO, IDEA, the regional Government of Extremadura and AGENEX, the Regional Government of Andalusia/Andalusian Energy Agency and the Regional Government of Castile-La Mancha. CIEMAT has been particularly helpful, facilitating the contacts of the consortium with the Ministry and providing us with a thorough context of energy policy and interests in Spain.

4.3.2.1 Energy policies and the place of STE in the Spanish landscape

4.3.2.1.1 Current energy mix in Spain

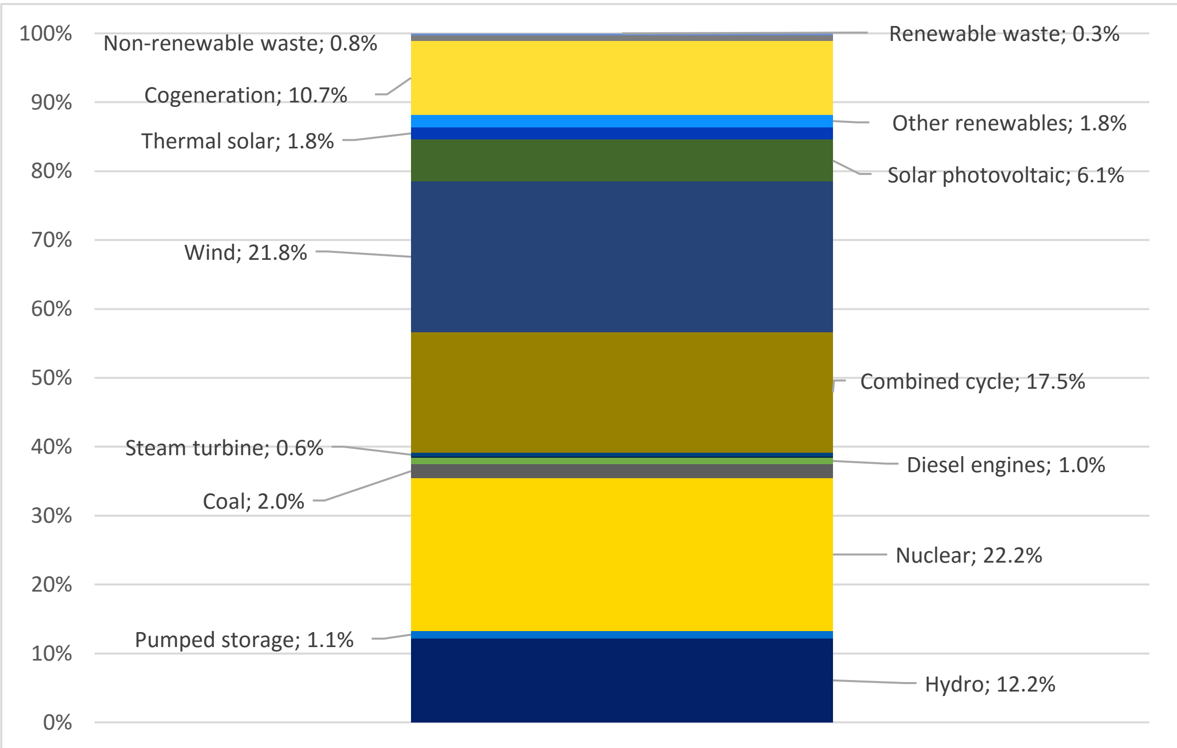


Figure 25: Power generation in Spain in 2020 (source: REE)

As shown in Figure 25, in 2020, fossil fuels represented 33,8% and nuclear 22,2% of power generation in Spain, while renewables accounted for 44,0%, ranking as first energy source.

The highest share of RES is represented by wind, which equals to 49,7% of the total RES generation and more than 20% of the total generation in Spain.

Figure 27 shows the data for energy consumption per sector in 2019. The three main energy consuming sectors are transport, industry, and private households, all three of them accounting for 84% of the total energy consumed in Spain. More precisely, the share of energy sources per sector is displayed in Figure 26. The share of gas accounts for more than a third of the industry sector and oil represents almost the totality of the transport sector. However, for households, the main sources are electricity and to a lesser extent gas and oil. This leaves space for further penetration of renewables in the different sectors.

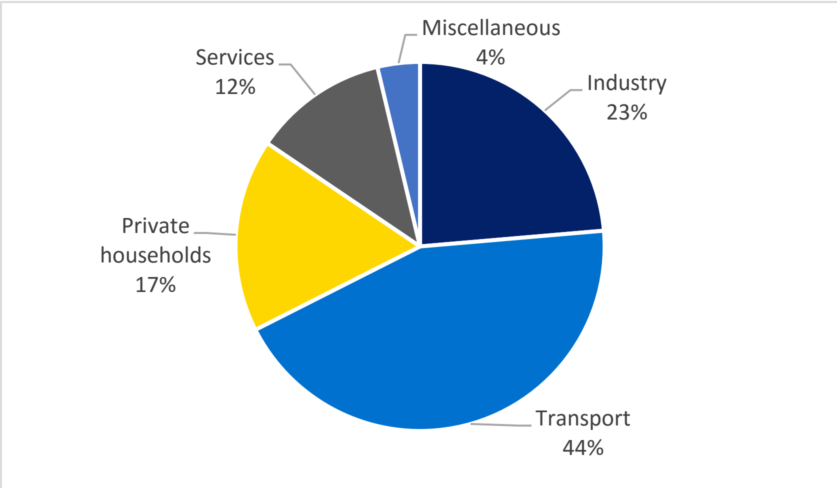


Figure 27: Energy consumption per sector in 2019 in ktoe (source: IDAE)

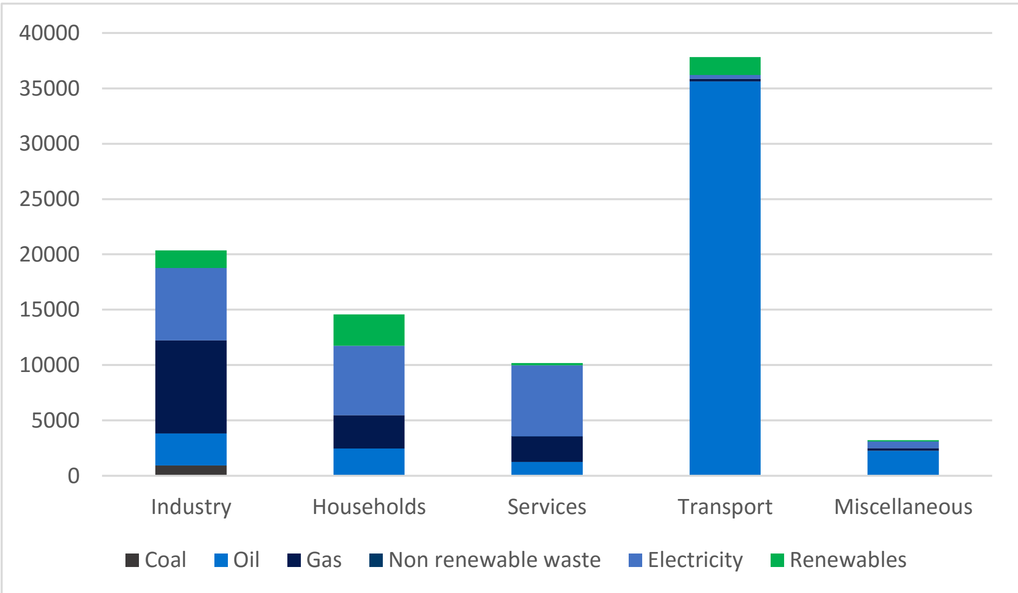


Figure 26: Share of consumed energy per sector in 2019 in ktoe (source: IDAE)

Regarding electricity production, renewables represent around 39% of the Spanish mix. Table 23 shows the total installed capacity per technology in Spain for electricity production. Wind has the largest installed capacity in the country, representing almost

25% of the total installed capacity. However, Spain remains a net energy importer, as shown in Table 24.

Technology	Installed capacity (MW)
Hydro	17,097.68
Pumped storage	3,331.4
Nuclear	7,117.29
Coal	5,733.225
Fuel + Gas	7.95
Diesel engines	769.59
Gas turbine	1,148.65
Steam turbine	482.64
Combined cycle	26,250.15
Non-renewable waste	428.071
Cogeneration	5,710.864
Hydroeolian	11.32
Wind	27,489.19
Solar photovoltaic	11,758.75
Thermal solar	2,304.013
Other renewables	1,090.295
Renewable waste	157.322
Total	110,888.383

Table 23: Total installed capacity in 2019 (source: REE)

Spanish electricity exchange balance in 2020 (MWh)	
Import	17,928.364
Export	14,648.779
Net import	3,279.585

Table 24: Spanish electricity exchange balance in 2020 (source: REE)

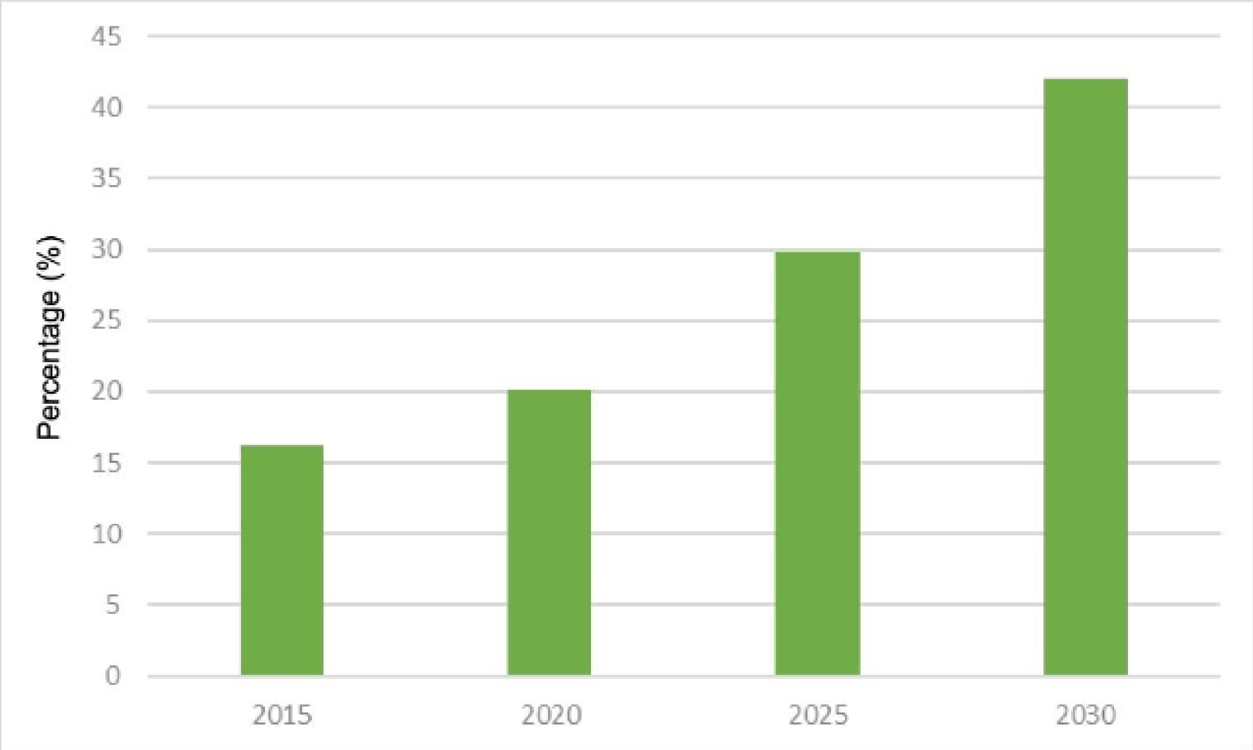
4.3.2.1.2 The Spanish NECP: the highest ambition for STE

Spain has submitted the most ambitious National Energy and Climate Plan (NECP[73]) in terms of STE, since it foresees to triple its current installed capacity for this technology, adding 5 GW to its fleet by 2030. More generally, Spain set the following targets for 2030:

- 23% reduction in greenhouse gas (GHG) emissions compared to 1990.
- 42% share of renewables in energy end-use.
- 39.5% improvement in energy efficiency.
- 74% share of renewable energy in electricity generation.

Figure 28 details the indicative contribution of renewables in energy end-use until 2030.

[73] *Available in full here: https://energy.ec.europa.eu/system/files/2020-06/es_final_necp_main_en_0.pdf*



Source: Ministry for Ecological Transition and Demographic Challenge, 2019

Figure 28: Contribution of RES to final energy consumption according to the NECP

Table 25 gives a detailed overview of the capacity targets for 2030, as mentioned in the NECP. To reach its targets, Spain plans to decrease its installed capacity in nuclear, waste and cogeneration, phase out coal, while almost doubling its wind capacity, tripling its STE installed capacity, and quadrupling its PV capacity.

Technology	2030 installed capacity (MW)
Wind (onshore & offshore)	50,333
Photovoltaics	39,181
Solar thermal electricity	7,303
Hydropower	14,609
Mixed pumped	2,687
Pure pumped	6,837
Biogas	241
Other renewables	80
Biomass	1,408
Coal	0
Combined cycle	26,612
Cogeneration	3,670
Fuel and fuel/gas[74]	1,854
Waste and other	341
Nuclear	3,181

[74] *Non-peninsular territories*

Technology	2030 installed capacity (MW)
Storage	2,500

Table 25: Prevision of renewable installed capacity in 2030 (source: NECP)

To favour this new penetration of renewables in the energy system, Spain has planned to develop new facilities for generating electricity using renewables. This represents 59 GW of new renewable installed capacity by 2030. The country plans to:

- Keep on supporting proven, mature technologies through competitive tendering mechanisms, and minimise the amount of public aid required.
- Adapt the public support mechanisms to the specificities of each not-yet-mature technology and of the different territories.

Four different mechanisms are thus envisaged:

- Calls for tenders for the allocation of a specific remuneration scheme: to promote annually at least the construction of 3,000 MW of renewable facilities, long-term recognition of a fixed price for the energy generated. The NECP specifies that "it will be possible to distinguish between different energy generation technologies depending on their technical characteristics, manageability, location criteria, technological maturity or anything else that may guarantee the transition to a decarbonised economy".
- Promotion of a diversity of actors and the existence of participatory citizen projects.
- Specific programmes for developing technologies (marine, offshore wind).
- Specific programme for islands.

Spain gives a specific importance to the flexibility of the energy system, to favour a higher penetration of variable RES in its system. There is a development programme for storage aiming at 6,000 MW of additional power. The choice of technologies will "depend on technology development and the relative merits of each alternative"[75]. However, a specific mention of thermal storage, "particularly linked to solar thermal technologies"[76] highlights the role which the whole value chain of the concentrated solar thermal technologies could play. More specifically, the NECP reads as follows:

> "In addition, it is important to note the increase in thermal storage that will occur, associated with CSP installations. Installations that increase their installed capacity by 5 GW between 2021 and 2030 and that have nine hours of storage using molten salt tanks."

Sector coupling is also explored as a potential way to bring more flexibility to the system.

[75] *Available in full here: https://energy.ec.europa.eu/system/files/2020-06/es_final_necp_main_en_0.pdf*

[76] *Available in full here: https://energy.ec.europa.eu/system/files/2020-06/es_final_necp_main_en_0.pdf*

In 2019 transport sector was the largest CO_2 emitter, accounting for 41% of total emissions from fuel combustion[77], however between 2020 and 2030 a decrease of 33% is expected in the sector. The main driving forces behind the decrease is a modal shift that will, according to the NECP, affect 35% of the passenger kilometres that are currently travelled in conventional vehicles and consumes less energy per passenger-km or tonne-km, as well as creation of low-emission zones, that will become widespread across cities with more than 50,000 inhabitants. Furthermore, renewable energy in mobility and transport will play a crucial role, reaching 28% in 2030 through electrification and the use of advanced biofuels.[78]

On top of energy-efficiency measures in transformation, transport and distribution, the promotion of high-efficiency cogeneration and urban heating and cooling networks have been part of the comprehensive strategy for energy-efficiency in cities. Support for RES for heating, cooling and off-grid electricity generation is mainly put into practice through subsidies for installed capacity from the autonomous communities. NECP encourages these communities, as well as local authorities to adopt the mandatory target of renovating 3% of the built and heated area of the public building stock, as this will achieve a much more ambitious energy-saving target. Promoting medium-temperature CST (90ºC-400ºC) for industrial heating and cooling is also a priority. In the period to 2050, the development and implementation of the next generation of thermoelectric solar technology will be promoted in order to increase manageability and renewable strength in the system at competitive prices.

Spain is still behind in terms of interconnections, reaching less than 5%. This makes Spain the only country not reaching the 10% target of 2020. To catch up on this delay, the development of new interconnections is planned:

- One with Portugal, to increase the exchange capacity to 3,000 MW.
- Three with France, increasing the interconnection capacity to 8,000 MW.
- A project between Aquitaine (FR) and the Basque Country (ES), the Bay of Biscay.
- An interconnection between Aragon (ES) and Pyrénées-Atlantiques (FR).
- An interconnection between Navarre (ES) and Landes (FR).

As a reminder, the EU target for 2030 should be of 15% by 2030.

4.3.2.1.3 Specific intermediate actions by the Spanish industry ahead of the CSP auction

Acting proactively ahead of the CSP auction in Spain, a set of so-called short-term (or intermediate) measures to support the economic recovery of the CSP sector has been proposed by the national industry. These intermediate measures point to the added value generated by TES in CSP plants as well as to new ways of exploiting existing CSP power plants.

[77] *Available in full here: https://iea.blob.core.windows.net/assets/2f405ae0-4617-4e16-884c-7956d1945f64/Spain2021.pdf*

[78] *Ibid.*

TES, as a key asset of CSP plants, enables storing energy in the form of heat at competitive costs and generating electricity whenever it is needed, independently from the weather conditions. According to Protermosolar, there are 27 CSP plants in Spain that were built without storage capacity, 10 out of which would benefit from installing TES facilities to provide dispatchable energy. Moreover, it is estimated that around 3 out of 18 CSP plants with already built-in storage could expand their capacity by installing a new TES system. Both cases, fully aligned with the NECP targets to increase the energy storage capacity in the country, have a comparable investment cost as a result of the requirements for more auxiliary equipment and expansion of the solar field, in addition to the new pair of storage tanks, however this cost is significantly lower to installing new CSP power plants.

In the same direction, the existing thermal storage capacity of CSP power plants could be used as a strategic reserve available to the system operator to serve the peak demand[79]. More specifically, CSP plants are typically built with a thermal storage capacity that corresponds to the maximum energy collected by the solar field and is thus necessary for daily production during the summer period. It becomes apparent that the total thermal storage capacity is underutilised during the rest of the year, representing an opportunity for the system operator to use it for a certain period (e.g., between 3 and 6 hours) during the winter, spring and autumn, to flatten the relative maximums of the pool prices. Considering that the curtailments of variable RES can be significant under a realistic scenario of operation conditions, CSP plants could install electric heaters to thermally store the excess energy from wind farms or photovoltaic plants with investment costs 50 times lower compared to large battery storage systems or pumping stations.

In this context, installing PV to partially cover the self-consumption of existing CSP plants has also been proposed as an intermediate measure to reduce the auxiliary consumption, but still supply CSP power to the grid. This measure is applicable to the total fleet of CSP power plants in Spain having an annual self-consumption of about 400 GWh that could be reduced to about 75%. To be applied, this approach requires the amendment of the current regulation in Spain to allow exceeding the current nominal potential of the plants with exclusively solar thermal and synchronous generation. Nevertheless, installing PV in CSP plants to reduce auxiliary consumption is not aligned with the political agenda of the Spanish government.

Last, a new conceptual design of central receiver CSP systems is also proposed to increase the overall power plant efficiency and, at the same, offer modularity and scalability to sizes similar to conventional thermal power plants[80]. The proposed modular and scalable design reduces the relative investments associated with the power block, and thus makes CSP power plants more cost-competitive, by introducing unit modules of heliostats and tower fields, with a north arrangement instead of circulating and transporting molten salts to a single storage system with a single turbine. Similarly to the case of the technology for parabolic trough collectors, this approach results in a standardised design with CSP towers approximately 100 meters high and heliostat fields equivalent to 30/40 MW.

[79] *See: http://www.cspfocus.cn/en/market/detail_2029.htm*

[80] *See: http://www.cspfocus.cn/en/market/detail_2170.htm*

4.3.2.1.4 Spanish CSP auctions

As stated in the NECP, auctions will be the main tool for the development of the technologies which will help to decarbonise Spanish electricity sector. The design of the auctions is based on the predictability and stability of the revenues to facilitate the investment decision and its financing. Priority should be given to installations that facilitate a more efficient energy transition. The design of the auction system should take into account the following elements:

- The effect of lower wholesale market prices at times of high renewable generation.
- The existence of discharges during times of high renewable generation.
- A potential increase in social opposition in some locations, due to a high concentration of projects in areas with greater resources, in addition to a possibly inefficient sharing of co-benefits.

On 30 December 2021, the Spanish authorities released a draft announcement for a RES auction with tentative date on 6 April 2022, applicable to CSP installations, either standalone or hybridised with PV or biomass[81]. Specifically, the main design parameters of the auction are:

- The total auctioned capacity is 360 MW including other technologies with a quota of 200 MW for CSP with 6h of storage. The maximum capacity to be allocated can be 381,6 MW (increased by 6%) if there is excess of demand.
- The allocation of the auctioned capacity will be solely based on the price (€/MWh).
- The tender process is applicable not only to new installations, but also to expansion or modification[82] of existing ones.
- The guarantee of participation is 60 €/kW, which amounts to 3-6 M€ for a CSP installation with a capacity of 50-100 MW.
- There is no restriction on the technology of the CSP installation (i.e., parabolic trough, molten salt tower, Fresnel, etc.)
- The maximum bid size is 100 MW.
- There is a limit of 50% per company applicable over the total auctioned capacity, meaning that no company can be awarded with a total capacity greater than 180 MW.
- CSP can be hybridised with either PV or biomass with the following capacity restrictions:
    - The PV power cannot exceed the CSP power and the annual operation hours must be in the range of 2.500-3.400h.

[81] *See: https://energia.gob.es/es-es/Participacion/Paginas/DetalleParticipacionPublica.aspx?k=479*

[82] *Modification applicable to installations older than 15 years.*

- The thermal power of biomass cannot be more than double the nominal CSP capacity and the annual operation hours must be in the range of 3.600-4.800h.

- The PPA duration is 20 years with a tariff corresponding to the amount of energy supplied considering the maximum annual operation hours (power*maximum annual hours*20 years). This means that if a power plant supplies this amount of energy earlier (i.e., before year 20), it can participate in the market with pool prices from that point onwards.
- The exposure rate to the market prices (market adjustment percentage) is equal to 15%. This means that if a CSP plant operator bids at a given time (e.g. 4:00 am) for a price of 100 units and at this moment the pool price is at 60 units, the adjustment of the difference with the market price is (100-60)*15%=6 units. In this case, the CSP plant operator would be remunerated with 100-6=94 units instead of 100 units (as the bid).
- The commercial date of operation shall occur by 30 April 2026 (4 years) to avoid penalties. Any operational power plant connected to the system prior to this date will receive only the wholesale market price.
- A strategic plan with estimates of the impact on the local employment and value chain must be submitted.

The Spanish industry voiced some disappointment at the terms in which the auction was announced, since the auction features are comparable across different technologies at a time following the initial stage of deployment of renewables in Spain and a swift transition from conventional fuels for electricity generation to renewables.

A solar thermal auction should simply focus on the functional assets of the CST technology responding most effectively to the actual needs of electricity systems in sunny countries. A one-for-all RES auction design as initially proposed would not do that, on contrary, it would call for proposals from the sector after a decade of standstill, leaving aside its most important benefits, resulting in a distortion of its role and its cost/benefit ratio (system value). From ESTELA's point of view, it is regrettable this will happen in the only country in Europe with excellent resources, site conditions and technological capacity to face the problem that other EU Member States will find almost impossible or very expensive to solve.

The auction features were perceived if the only objective would still be a least-cost approach applied to a technology that is logically more expensive than the non-dispatchable ones, but with the best cost/benefit ratio on the way towards decarbonisation.

The long-awaited CSP auction in Spain is expected to be further delayed due to regulatory barriers. Under the existing legal framework, the hybridisation of CSP (or any other RES) with biomass bears the risk of not being eligible for the special remuneration regime (Regimen Retributivo Especifico) applicable to RES. As of spring 2022, the Spanish Government prepared a Royal Decree addressing this issue, however the new law has not entered into force yet (at the moment of reporting). After the release of the new regulation, the official announcement for launching the CSP auction will be published, but there will be a period of at least 2 months to submit project proposals. This means that the CSP auction results in Spain are not expected earlier than mid of September 2022.

4.3.2.2 Energy regulation in Spain

In Spanish energy sector MITECO has overarching jurisdiction at national level and leads on energy policy formulation. The main responsibilities of the ministry include:

- Regulations concerning energy and mining matters, which are shared with other ministries for evaluation.
- Legislation overseeing the tariff structure, prices of energy products, and levies and tolls (though the regulator sets the rates).
- Legislation to save energy, promote renewable energy, and support new energy and mining technologies.
- Legislation of measures to ensure energy supply.
- Legislation and actions related to the demographic challenge.

Moreover, under Spain's decentralised system of government, regional administrations have considerable authority over energy policy development and implementation, making effective co-ordination between the centre and the regions even more critical to successful enactment of energy strategies in Spain. The autonomous communities have legal competencies related to energy, primarily in authorising power plants of less than 50 MW, and distribution networks of electricity and natural gas. They are also heavily involved in designing and implementing climate change, energy efficiency and renewable energy policies at the regional level[83].

ESTELA conducted interviews with the Government of Extremadura and AGENEX, the Regional Government of Andalusia/Andalusian Energy Agency, and the Regional Government of Castile-La Mancha. During these interviews the follows similarities across three regions were made clear:

- Following the NECP, local energy strategies (until 2030) are developed; each includes lines of action and measures to guarantee that each region can fulfil objectives proposed to contribute to the NECP.
- A large number of renewable energy production projects are in the processing phase, including hybrid projects - not only new CSP plants with combined technologies, but also for already running plants incorporating storage or more than one technology.
- In order to simplify the energy transition, regional governments are easing the bureaucracy burden with procedural simplification, shortening of the deadlines, efficiency in Gerard to permit granting, etc.

Extremadura, one of the CSP leaders in Spain with 43% of renewable energy produced by CSP (2020) and with 17 plants of which 11 are with storage, is in line with the objectives of the NECPs and is supportive of the national policies. Based on technical resources,

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[83] *Available in full here: https://iea.blob.core.windows.net/assets/2f405ae0-4617-4e16-884c-7956d1945f64/Spain2021.pdf*

connection capacity and Next Generation EU funding available, the region is estimated to add 1500 MW of new CSP in upcoming years. Furthermore, Extremadura is expressing strong interest in a double approach of the use of these funds, both boosting the energy transition and regional development. In order to support the future development, the region is very efficient on its permit and file processing, having created a specific processing unit for renewable plants, integrating parts of the environment and industry and energy units.

Development of renewables has a principal role in Andalusia, with growth of CSP playing a significant part both at regional and national level. While as of now no concrete objectives are set yet, some 26000 MW of new renewable energy capacity is expected, with solar energy being the biggest contributor. Moving forward, hybridisation will also have a significant role, bringing new plants with combined technologies, as well as further development of already running plants, incorporating storage or adding another technology (e.g. combination of PV and CSP). In the region a significant limitation is access to grid. While significant number of PV projects have already requested access to the grid, so far, no CSP plants have followed. However, just like in Extremadura, regional government in Andalusia is putting high hopes on Next Generation EU funding.

In Castile-La Mancha, 53% of energy generated is from renewable sources. Currently in the region more than 400 energy-related projects are underway, with total capacity of 10 GW and different renewable technologies and sizes. If all these projects are granted sufficing funding, the regional network would be almost saturated by 2023 and by 2030 the region would cover 100% of its the domestic demand with renewable energy. Based on the large number of applications for renewable projects received so far, regional government is estimating to have an investment volume of approximately 20000 million euro between 2020 and 2030 and an estimated 9000 to 16000 new jobs a year.

In order to support the spike in new projects, regional government of Castile-La Mancha has enabled a priority processing procedure – a regulatory instrument to streamline procedures by providing some projects a status of strategic importance in the region. They benefit of a procedural simplification, shortening of deadlines and priority processing compared to other projects, as well as simplification for urbanistic regulatory procedures.

4.3.2.3 Energy transmission system in Spain

The development and strengthening of the electricity transmission and distribution infrastructure must be adapted to the forecast development of renewable generation. While planning the transmission network the stakeholders must consider that in the coming decades the environment in which they will operate will undergo substantial changes. In addition to the technical and traditional requirements of security of supply and reliability, as well as the economic and financial sustainability of the electricity system, it will also require the compatibility of the development of the electricity transmission network with environmental restrictions that seek to minimise the overall environmental impact. The development of infrastructures will require a speed up of this process to fulfil the objectives of maximising the penetration of renewables into the electricity system. Unfortunately, current Spanish regulations don't stimulate these objectives.

REE's, Spanish TSO's main responsibility is to have the system up and running, while in their TSO regulated environment, they cannot promote specific energy sources and the related investments. From REE's point of view, their role is to operate the transmission power system so to ensure reliability (adequacy of means and security of operation) independently regardless the available energy sources. Incentives to promote or discard technologies come from the political sphere, embedded in national regulations, which prevents REE to control CSP plant storage, which at the moment reaches a capacity of 870MW with an average of 8 hours of storage, to their needs. Under the Spanish regulation with the current tariffs in force, all CSP plants are incentivised to provide the electricity after the sunset, which is not incentivising the owner of the plant to follow the TSO needs at any time of the day. This is detrimental to a correct assessment of the system value of the TES.

Due to the a.m. regulatory limitation, REE could not formally confirm the real flexibility added by CSP plants to the operation of the Spanish system; however, REE does not dispute the role of CSP in a given electricity system in case the management of the storage is controlled by the TSO.

4.3.2.4The Spanish industry: a worldwide recognised knowledge

Spain is a world leader both in installed and technological capacity, generating best know-how and accelerated by excellent natural resources across the country. Based on years-long experience, numerous Spanish companies in the CSP sector are beginning to contribute to ambitious projects in other regions of the world (USA, North America, Middle East, China, India, Australia, etc.). Currently Spain has 50 plants in operation, as shown in Figure 30[84], with a total of 2,300 MW of power, making the Spanish CSP market one with the biggest operating capacity in the world. Figure 29[85] details the annual generation of power by STE plants.

Thanks to the high level of solar radiation, especially in southern Spain, the country could become a major exporter of green energy in the future, helping other European countries to meet their NECPs objectives. According to its NECP, the country plans to increase its CSP fleet by 5 GW by 2030, starting with the auction of 200 MW of new CSP capacity (expected in 2022). Although no additional plants have been built in Spain since 2013, the conditions and design parameters of this CSP auction set by the Spanish authorities will have a crucial impact on the entire CSP sector, and especially on the interest of investors for more CSP projects, not only in Spain, but also across Europe.

[84] *Helena Martín, Jordi de la Hoz, Guillermo Velasco, Miguel Castilla, José Luís García de Vicuña, Promotion of concentrating solar thermal power (CSP) in Spain: Performance analysis of the period 1998–2013, Renewable and Sustainable Energy Reviews Volume 50, 2015, pp. 1052-1068, https://doi.org/10.1016/j.rser.2015.05.062.*

[85] *Source: https://www.esios.ree.es/es/analisis*

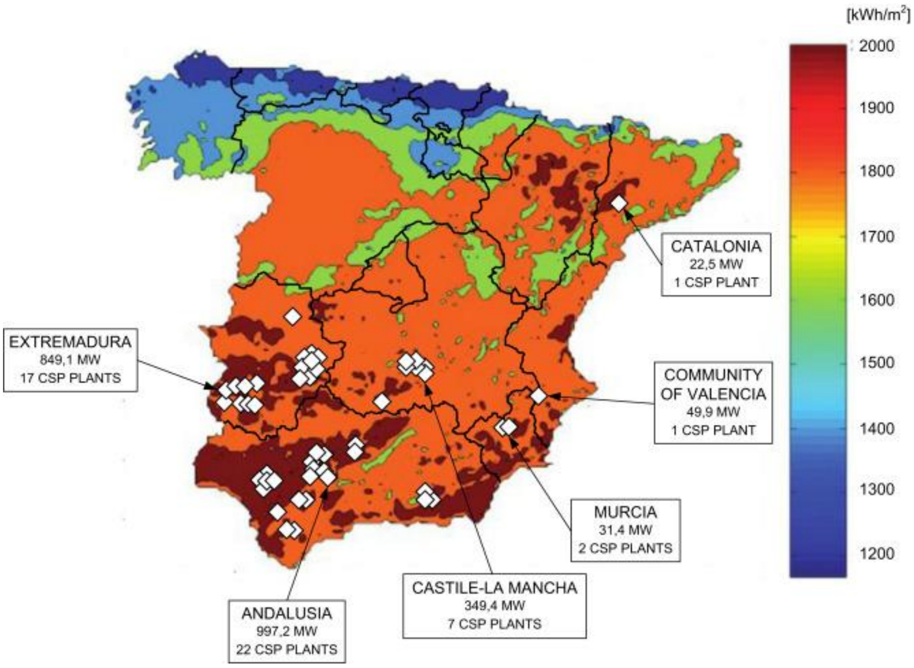

Figure 30: CSP power plants in Spain

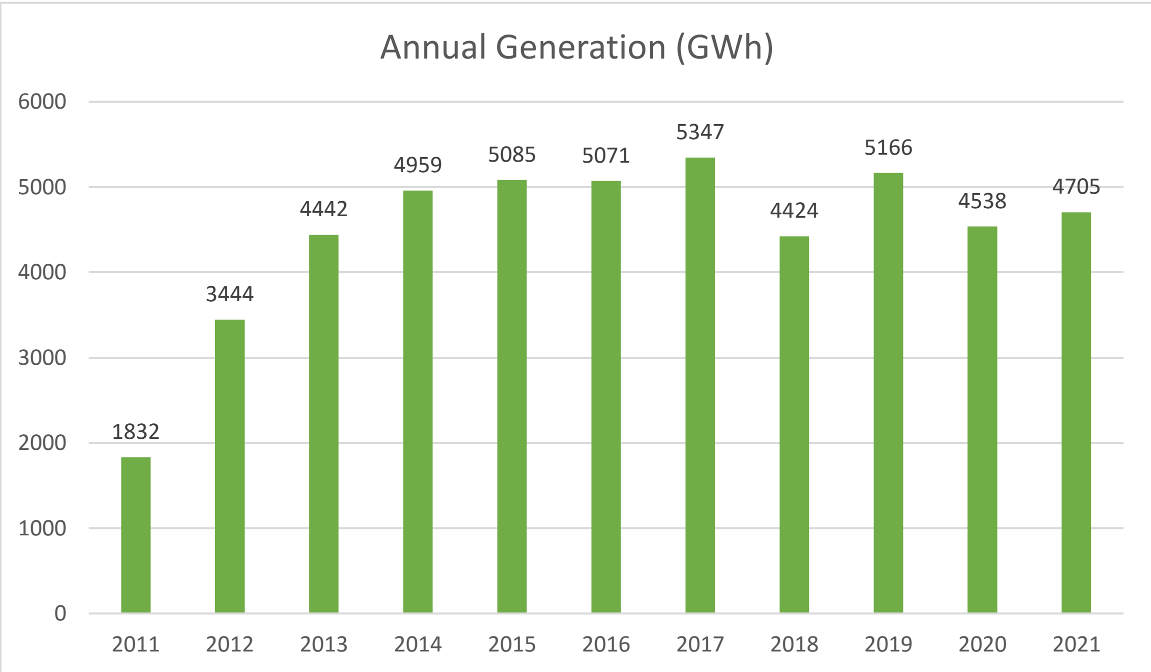

Figure 29: Annual generation of power by STE plants (GWh)

4.4 Key findings

4.4.1 R&I

4.4.1.1 Excellent research collaboration at international level

Spain is participating very actively and even promoting international entities related to R&I activities of the CST sector. Spain is currently coordinating the EJP on CSP of EERA and the PSA will be the central node of EU-SOLARIS[86] (the European distributed facility of research centres devoted to CST). Many Spanish R&I entities have participated in the preparation of the updated Implementation Plan for CSP of the SET Plan. The number of Spanish researchers participating in the several standardisation teams of the international technical committee IEC-TC117 has been very high since the launching of this standardisation technical committee in 2012, and the Secretary of this international committee is a researcher from CIEMAT.

Spanish researchers are also very active in the working groups implemented in the several tasks of SolarPACES[87], which is one of the Technology Collaborative Programmes of the International Energy Agency. It is also worth mentioning the long-lasting collaboration between CIEMAT and DLR for the joint development of projects at the PSA facilities.

Finally, a strong link also exists between Spanish R&I entities and non-European research centres (i.e. CSIRO, NREL, MASDAR, IEECAS, QATAR Foundation, etc).

4.4.1.2 Substantial need for more public funding on R&I

Although the number of R&I projects underway in Spain is already high, Spanish stakeholders have many more innovative ideas not only to improve the current technology, but also to develop new commercial applications. However, the level of public funding available for R&I is rather small, thus jeopardising the development of innovations. At European level, the reduction in the funding devoted to CST technologies within the European Framework Programmes has been very significant. A substantial technology improvement is almost impossible with such a low budget.

Even though more R&I topics are usually proposed by Spain, Germany, Portugal, France, Italy, Cyprus, Turkey and Greece within the working group preparing the European Work Programmes, such request is usually ignored by the European Commission, because the priorities defined at a higher level within the EC are different from CST technologies. Perhaps the reason for this lack of interest at higher level is due to the fact that only the Southern European countries have a high level of direct solar radiation.

In spite of the low attention paid so far to the demands of Spain, Germany, Portugal, France, Italy, Cyprus, Turkey and Greece to increase the budget devoted by the European Commission to CST technologies, the national contacts of these countries will keep on this request.

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[86] *See: http://www.eusolaris.eu/*

[87] *See: https://www.solarpaces.org/*

4.4.1.3 Complex administrative processes limiting the efficiency of public R&I entities involved in projects

There exists a problem in Spain that is jeopardising the R&I activities of some public centres, like CIEMAT. This problem is the unsuitability of the administrative and management rules imposed to these centres, thus putting significant barriers to an efficient collaboration with the industrial sector and other R&I centres. The current administration and management procedures imposed to these centres are incompatible with the funding rules of European Framework Programmes, because more and more often the funding obtained from the European Commission at the beginning of the project is not internally available later on, when the projects under development need to use those previously received funding in accordance with the project planning and programme. This problem could be solved by the Spanish Administration by means of the implementation of rules similar to those implemented in the Spanish Universities and other R&I centres where the EC funding received for the projects is available throughout the projects until their finalisation.

4.4.1.4 Promising future of green energy export

The export of green energy such as STE or hydrogen is considered a feasible activity in Spain for a future decarbonised energy supply in Europe. Having in mind that Spain features the best solar resources in continental Europe and good wind resources, as well as a good level of interconnection to France and Morocco, electricity exports are not only feasible but make also much sense, together with the production of green hydrogen. However, significant progress both in Spain and in transit countries across Europe (use of cooperation mechanisms) is required to make this possibility a reality. A specific part of the CST technology (thermal storage) provides substantial opportunities to use the excess of green electricity to produce hydrogen or deliver electricity on demand.

Finally, a significant R&I effort is currently devoted by Spanish stakeholders to develop cost-effective processes to produce green fuels using thermal energy produced with CST technologies and electricity from PV or wind power plants. Development of innovative catalysers for this purpose is at present pursued in several national and European projects.

4.4.2 Industry

4.4.2.1 The expected auction in 2022 will determine CSP's future in Spain

The long-awaited CSP auction in 2022 will be the first time after more than 10 years without new projects when new / real costs will be set, signalising to the industry in Spain and beyond about the current potential of CST in Europe (type of projects and their costs).

The auction results in Spain will also provide the necessary input for defining realistic cost targets in the CSP IP Update over the next decade.

4.4.2.2 TES – the next step for already existing plants

Spain's electrical system will increasingly need storage capacity to ensure its reliability while substituting fossil sources, especially natural gas, that is currently used to cover demand mainly after the sunset. More than half of CSP plants in Spain were built without storage, out of which 10 could benefit from installation of TES facilities. Furthermore, there are 16 plants that have storage for more than the 6 hours and many of these facilities could increase their storage capacity by around 3% by adding molten salts to the tanks where thermal energy is stored, accompanied or not by an extension of the solar field. Following these steps would provide additional dispatchable energy, double the storage capacity and open the door to replace the natural gas.

4.4.2.3 Unlocking the full potential of CSP in Spain depends on the design of relevant auctions and adjustments of current regulatory conditions

Several features of any auction about new renewable capacities can make CSP projects either non-viable or artificially expensive. These are:

- The connection to the grid is a separate process from the tariff, with significant risks in getting one without the other.
- The duration of the PPA reduced to 12 years (instead of at least 20 years, even if 20 years is much lower compared to other countries, e.g., 35 years for DEWA CSP Tower and Trough Projects in UAE).
- The period between auction results and date of commercial operation. If shortened to 3 years instead of 4.
- The request to achieve min 3,000 and max 4,000 operation hours, without further criterion.

  To match this criterion, all promoters would try to bid all day long and into the night hours, which will lead to a dimensioning of the storage capacity to 7, 8 or 9 hours max and an unavoidable overlapping generation with PV during the daylight hours. All this only with the objective to reach 3000 to 4000 hours of operation. Instead, the auction should be exclusively about night-time generation.
- An exposition rate to market prices above 10-15%.

  If a CSP plant operator bids for a given time (e.g. 4:00 am) a price of 100 units and at this moment the pool price is at 60 units, 25% of the difference to market price is 10 units: So the operator of the CSP plant would not be remunerated 100 units (as bid) but 100-10 = 90 units. This condition leads bidders to speculate on other bids compared to the current pool price and may penalise the bidders up to 15% artificially, i.e. without any benefit to the system. And no CSP plant will ever be operated like batteries, searching for short peaks of demand. The real time conditions are different (in the sense that demand does not evolve just along the current instant pool price), but they would easily penalise CSP generation. This would result below optimum for a technology that should provide night baseload generation.

Legal / regulatory barriers:

- Currently, the Spanish legislation does not allow hybridisation between concentrated solar and other technologies such as biomass, etc. This specific feature is also the reason for the delayed date for the auction in 2022. Overall, this appears to work against the political goals of the Spanish government.
- The existing storage units in existing CSP plants are not managed by the Spanish TSO that cannot use their capacities for balancing the system. This is also why the Spanish TSO on the one hand recognises the potential of CSP, but on the other hand cannot formally confirm the benefits of the technology for mitigating the various TSO operational challenges. Just green night-time energy is not systematically the priority of the TSO who might prefer to keep the storage unused while the remuneration scheme for the owner/operators of the plant incentivises a quantitative approach to generation "independently" of the system needs (see paragraph above related to operational hours).

4.4.3 Integrated findings

4.4.3.1 Strong partnerships between industry and R&I entities

- The 50 CSP plants installed in Spain from 2007 to 2013 gave to Spanish stakeholders an excellent background that was then used in commercial projects implemented abroad. The number of research groups working on CST technologies and their applications has been growing in Spain during the last 15 years, thus providing the industrial sector with an excellent scientific support.
- The strong collaboration between the CST industrial sector and the Spanish R&I groups is clearly depicted by the high number of research projects that have been developed or are still underway with the participation of universities, technological and research centres. At present, there are more than 10 Spanish universities with important R&I groups, which produce a high number of scientific papers and Doctoral Thesis every year.
- The excellent know-how and experience acquired by the Spanish industrial sector and the high number of R&I stakeholders is complemented by the outstanding CST experimental infrastructures existing in Spain, the PSA being the best exponent. Nowadays Spain is the European country with the most comprehensive set of R&I infrastructures, which include both laboratories and large outdoor life-size facilities. The existing facilities are suitable not only for components evaluation and qualification, but also for projects demanding a solar power of up to 4 MWth.
- Taking into consideration the excellent background and R&I infrastructures existing in Spain, it is expected that the 5 GWe of new CSP plants foreseen in the NECP for the period 2021-2030 will reactivate the CST industrial sector in Spain, with new commercial and R&I projects promoted by the Spanish stakeholders. If the CSP target is not met, this implies that more fossil-fired power plants will be needed.

4.4.3.2 CSP has a key role to play in future electricity markets

- Innovations on receivers, heliostats, parabolic troughs and new fluids combined can lower the LCOE of CSP installations in alignment to the targets set in the SET plan for the CSP sector.
- Further cost reductions are possible by hybridising CSP with other RES technologies, especially PV.
- The industrial maturity of CSP combined with its ability to supply synchronous and dispatchable power to the grid render it as the ideal technology to phase out natural gas and provide short-term answers to the challenge of a quicker transition to RES.
- In the context of the support CSP plants can provide to the electricity system (first at national level, and internationally if subject to cooperation mechanisms promoted by the EC), CSP is the cheapest and available alternative to the use of natural gas – which appears highly relevant under the energy crisis conditions amplified by the belligerent intrusion of Russian into Ukraine

4.4.3.3 Increasing interest for other uses of CST

- In Spain (as in most European member states), authorities are scrutinising the use of CST for industrial process heat and solar fuels market/applications, deemed to have a wider macroeconomic impact both for large industry player and SMEs.
- There is also an increasing interest in solar fuels, especially on photothermal process combining thermal energy and PV electricity.

4.4.3.4 CSP brings added value in economically stressed, rural areas

- There is a clear supportive position to CSP at least in 3 regions (Extremedura, Andalucía and Castilla-La Mancha) based on their respective experience with CSP plants in the first deployment phase of the technology in Spain regarding the job creation effects and increased local tax income. This is why the local authorities in these regions could provide additional funding support or support in kind (land made available at low cost) to developers by which the siting of new CSP plants in these regions would become very attractive and contribute to reducing the overall costs of the plants.

4.5 Aligned conclusions and recommendations

- The ambitions and specific objectives of the country should be realigned according to the dispatchability/manageability of the considered technology. An effective way to translate the complementarity between single RES technologies into efficient, market-based procurement mechanisms, is two-fold: on the one side the auction design should provide viable conditions for blending technologies, especially related to the exposure to market prices, and on the other side to use different evaluation criteria for each of the technology involved regarding their proper system or macro-economic value.
- So will the results of the expected auction in 2022 be exemplary in the full sense of the word, namely: it will reveal the type of projects and the costs levels that can be envisaged short term in Europe under European/Spanish regulatory conditions and bearing in mind of the market volume provided by the auctions. The market volume and identified project pipelines will be the main factor of further cost reductions (economies of scale), and the financial conditions offered by European banks and possible governmental incentives will determine the level of costs.

  For these reasons, the design of future auction is pivotal for the deployment of the technology in Spain and should be adjusted regarding the 4 specific aspects listed in section 4.4.2.3.
- In this context, the highly developed Spanish R&I sector on CSP - if still benefitting from a stable public funding - can also contribute to the relaunch of CSP/T in Spain in the upcoming years via incremental innovations in new CSP plants and new applications for process heat or solar fuels (see above section 4.3.1.2).

  Such incremental performance improvements, when aggregated in new plants or when revamping existing plants (e.g., added storage facilities) can raise the efficiency and therefore the commercial viability of new projects, only if they can at least partly offset the additional financial burden imposed by banks to developers for de-risking innovation in commercial projects.
- It appears advisable to ensure that the Spanish TSO can control the use of the storage capacities in plants with such capacities, but without remuneration loss for the owners/operators of the plant which would occur under the current regulatory regime. This could only be achieved by a reassessment at system level of the combined impact of the current regulatory conditions and some possible adjustment of the applicable remuneration schemes.
- Similarly, the applicable regulatory conditions should support the possibilities to optimise the use of CSP storage during the *winter* period – where a substantial part of the storage capacity in the plants remains unused – and motivate plant owners to offer this capacity to the TSO.

4.6 Glossary

AEI	State Research Agency
CDTI	Centre for Industrial Technological Development
CSP	Concentrated Solar Power
CST	Concentrated Solar Thermal
EC	European Commission
EJP	European Joint Programme
EU	European Union
GWh	Giga Watt hour
H2020	Horizon 2020
IDEA	Institute for Diversification and Saving of Energy
kWh	Kilo Watt hour
LCOE	Solar Thermal Electricity Cost
MCIN	Ministry of Science and Innovation
MITECO	Ministry for the Ecological Transition and the Demographic Challenge
MW	Mega Watt
MWh	Mega Watt hour
NECP	National Energy and Climate Plan
PEICTI	State Scientific, Technical and Innovation Research Plan 2021-2023
PPA	Power Purchase Agreement
PSA	Plataforma Solar de Almeria
PV	Photovoltaic
R&I	Research and Innovation
REE	Red Eléctrica de España
RES	Renewable Energy Sources
SET-Plan	Strategic Energy Technology Plan
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TSO	Transmission System Operator

4.7 Appendices

4.7.1 References

Spain – R&I

CENER - Centro Nacional de Energías Renovables website [online]

CIC-Energigune website [online]

CSP Solar ERANET website [online]

EERA - European Energy Research Alliance website [online]

Eureka website [online]

Instituto IMDEA Energía website [online]

Plataforma Solar de Almeria website [online]

Protermosolar website [online]

SOLARCONCENTRA website [online]

SolarPACES website [online]

TECNALIA website [online]

TEKNIKER website [online]

Spain – Industry

CSP FOCUS, "Concentrated Solar Power, renewable and storage, by Luis Crespo (Protermosolar)", [online]

CSP FOCUS, "Luis Crespo participates in the SolarPACES concentrated solar power conference"[online]

ESIOS, "Sistema de Información del Operador del Sistema" [online]

Helena Martín, Jordi de la Hoz, Guillermo Velasco, Miguel Castilla, José Luís García de Vicuña, Promotion of concentrating solar thermal power (CSP) in Spain: Performance analysis of the period 1998–2013, Renewable and Sustainable Energy Reviews Volume 50, 2015, pp. 1052-1068. [online]

Institute for Diversification and Saving of Energy, "Balance of Final Energy Consumption for Year 2019" [online]

International Energy Agency, "Spain 2021 – Energy Policy Review" [online]

International Energy Agency, "Spain 2021. Energy Policy Review" [online]

Red Eléctrica de España, "Cross-Border Exchange Balance - Physical (MWh)", from 03/2021 to 02/2022 [online]

Secretary of State for Energy, "Call for the third auction for the granting of economic regime for renewable energies" [online]

Spanish NECP [online]

4.7.2 Meeting guidelines

See APPENDIX.

4.7.3 Interview guidelines

See APPENDIX.

5 Chapter 5: Portugal

5.1 Structure of the document

The "Integrated Country Report – Portugal" aims to provide a global and structured approach of the country's profile regarding potential interest to STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2. Since no partner from Portugal is part of the consortium, information for the R&I part were drawn from the different interviews ESTELA had in the frame of WP2 activities, as well as from Deliverable D.1.2, Report on Current Framework Conditions to which R&I partners contributed. The aim is to reflect:

- The expressed need for manageable RES energy by the country of focus and the strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.
- The construction of a defined framework for funding and its reception by relevant audiences.
- The evaluation of performance of the funding frameworks.

Section 5.2 summarises the tasks which were carried out, both on R&I (5.2.1) on the industrial (5.2.2) side. This gives an overview of the intelligence collected and of the final key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Proposition of a reshaped funding framework based on feedback from stakeholders and the Implementation Working Group.
- Dissemination of information about the funding opportunities and impact evaluation.
- Meeting with relevant stakeholders, i.e. at Ministry, Transmission System Operator (TSO) and Regulatory Authority levels, as well as key players from local industries and civil society.
- Brokerage events and joint industry-R&I national events.

A deeper analysis of the context of each country is provided in section 5.3, first for the research section (5.3.1) and then for the industry (5.3.2). Each of these sections provides a global overview of the different factors influencing the development of funding and commercialisation of STE applications. More precisely, it aims to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Portugal.

Based on these observations, integrated key findings are drawn in section 5.4. They highlight encountered challenges and existing opportunities and draw a picture of the potential synergies between R&I and industry structures.

Last but not least, section 5.5 suggests strategic actions to continue opening doors for STE in Portugal, in an overarching approach to further support the development of STE, combining R&I and industry perspectives to offer thorough advice.

5.2 Summary of undertaken activities

Portugal has been under the scope of analysis from February 2020 until March 2022. The Covid-19 pandemic has slowed down the working process. Notably, ESTELA has collaborated with CIEMAT regarding the information related to R&I. Furthermore, as the consortium does not include any Portuguese partner, ESTELA received a strong support from DGEG, Energy Services Regulatory Authority (ERSE), LNEG and Portuguese Association of Renewable Energy (APREN) to maximise impacts and meaningful results.

The following chapters will describe the work undertaken in Portugal and analyse the challenges and opportunities met in the country.

5.2.1 R&I methodology

To have a wide overview of the R&I landscape of Portugal the following activities were carried out:

<table>
<tr><th colspan="2">List of activities</th><th>TIMELINE</th></tr>
<tr><td colspan="2">Documentation phase</td><td>Oct. 2021 - Nov. 2021</td></tr>
<tr><td colspan="3"><u>Aim:</u> To collect the information available about R&I in Portugal related to CST technologies (stakeholders, research centres, funding sources,..)</td></tr>
<tr><td>Description:</td><td colspan="2">Since there is no Portuguese partner in the HORIZON-STE project and taking into consideration the synergies between this Integrated Country Report and the content of the National Concept Note of Portugal to be elaborated within the framework of WP3 in the European SFERA-III project, people responsible for that Concept Note were contacted by CIEMAT to get all the information available about R&I in the Portuguese CST sector. People from the Cyprus Institute (Cyprus) and University of Évora (Portugal) were contacted, thus getting the intended information about industries, research centres, research facilities and funding sources in Portugal for R&I activities related to CST technologies and applications.</td></tr>
<tr><td colspan="2">Processing of information and writing of report</td><td>Dec. 2021 – Mar. 2022</td></tr>
<tr><td colspan="3"><u>Aim:</u> To write the sections devoted to R&I in this Integrated Country Report of Portugal</td></tr>
<tr><td>Description</td><td colspan="2">All the information collected during the documentation phase was analysed and processed by CIEMAT in order to get the R&I landscape of Portugal for CST technologies and applications, especially those directly related to the SET Plan for CSP.
The updated list of national and European R&I projects prepared by CIEMAT in 2021 within the EERA Joint Programme of CSP with the inputs delivered by the members of this EERA JP was also analysed to see the R&I activities currently underway in Portugal and the topics covered.
It was also included in this analysis the information collected by CIEMAT from Portuguese entities when preparing the Deliverable D1.4 ("Report on options for financing instruments and schemes") of HORIZON-STE project.</td></tr>
</table>

List of activities	TIMELINE
	The result from this analysis is given in section 5.3.1 of this document (Overview of the context in Portugal: R&I Landscape”). Key findings from this information analysis and processing are given in section 5.4.1.

5.2.2 Industry

5.2.2.1 Foreseen activities and implementation challenges

To favour a sustainable launch of STE in studied countries, ESTELA designed a general process unfolding in three steps with flexibility to adapt to specific country challenges:

PHASE 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and Portugal’s strategies on its procurement / possible changes in the relevant framework conditions
Encountered challenges	To find the right interlocutor Low answer rate to interview requests Mixed information received from different interlocutors
Applied mitigation	- Help from DGEG and LNEG to identify relevant stakeholders - General translation of official documents from Portuguese to English - Confrontation of different sources with the official source
PHASE 2	
BROKERAGE EVENT	
General aim	Assessment and presentation of potential solutions using CSP/STE
Encountered challenges	- Outbreak of covid-19 global pandemic - Little renewable solar in the energy mix and strong place of hydro
Applied mitigation	- Promotion towards ESTELA’s members of the upcoming “2020 Solar Auction (with or without storage)” - Realisation of a modelling study introducing STE in the Portuguese energy grid - On-line meetings with national stakeholders
PHASE 3	
JOINT NATIONAL EVENT	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	- Outbreak of covid-19 global pandemic - Not enough data collected yet
Applied mitigation	- Awaiting the end of the pandemic to evaluate the possibilities

5.2.2.2 Carried out activities

LIST OF ACTIVITIES	TIMELINE
BACKGROUND RESEARCH	Phase 1 Feb.-Mar. 2020

Aim: To collect relevant information to better understand the energy landscape in Portugal, the potential challenges for the development of STE and the needs of the country

Description

Desk research: Collect of information based on available information on official websites (e.g.: DGEG, ERSE, REN, European Commission, APREN ...), academic studies or reports by consultancies

Stakeholder mapping: Analysis of the specific relevant departments and actors for each identified target group

Exchanges with DGEG and LNEG on relevant contacts and existing knowledge of the local situation

Exchanges with APREN on existing challenges and potential creation of an STE business case to be presented to the Ministry

PRELIMINARY TALKS	Phase 1 Mar.-Dec. 2020

Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable RES, the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions

Description

Ideally, this phase aims to establish a first physical contact with the three key stakeholders in Portugal regarding energy policy, namely TSO, the Ministry and the Regulatory Authority.

However, as the Covid-19 pandemic forced EU borders to be closed and travels to be restricted, HORIZON-STE could not organise these meetings and had to hold them online

LNEG: Interview with the Director of LNEG, three researchers from the Renewable Energies and Energy Efficiency Unit and a technical officer from that same unit

Sec. of State of Energy Interview with two advisors to the Secretary of State of Energy

DGEG Interview with two stakeholders from the Research and Renewables division

REN: Interview with three stakeholders respectively involved in Network Planning, Studies and Regulations, and Grid Connections

ERSE: Interview with four stakeholders respectively involved in Infrastructures and Networks

SOCIO-ECONOMIC IMPACT ANALYSIS	Phase 1 May – Nov. 2021

Aim: To have projections on the potential socio-economic impact of the development of CSP in Portugal. This would be used as a basis for the narrative to be presented to Portuguese officials.

Description

Two units from LNEG (Renewable Energies and Energy Efficiency Unit and Resource Economy Unit) have helped ESTELA having a clearer overview of specificities of the Portuguese landscape regarding both renewable energies at large and CSP. Data on created RES employment between 2014 and 2018 per technology has been provided to weight the potential contribution of CSP in this landscape. Based on data from Spain, since the labour and economic structures are similar to Portugal, LNEG has projected potential employment

LIST OF ACTIVITIES	TIMELINE
creation in the CSP sector in Portugal by 2030. This could represent around 3,840 direct and indirect jobs in 2030 only. Results of this analysis were discussed with APREN and a joint letter for the Ministry of Ministry of Environment and Climate Action was drafted.	
PHONE INTERVIEWS	Phase 1 November 2020
Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of Portugal's energy strategy and potential need for manageable RES	
Description Industry: Interview to gather insights into renewable portfolio, conditions for a technology to be interesting, current role in the energy transition in Portugal. APREN: Interview with the President of APREN	
BROKERAGE EVENT	Phase 2 Aug.-Dec. 2021
Aim: To have a broad overview of STE perspectives in Portugal through existing and potential solutions using STE, from both the R&I and industry sides.	
Description However, ESTELA has promoted the "2020 Solar Auction (with or without storage)" in Portugal which allows for the participation of CSP technologies, thanks to a third remuneration scheme which recognises the importance of valuing flexibility and would thus compensate capacity and not only energy produced, as part of the criteria. The announced dates are on 24-25 of August 2020, for a total of 700MW/MVA total, in different lots, all located in regions of Alentejo and Algarve. ESTELA commissioned study on the potential of CSP in Portugal until 2030 using Inductive Projection Planning. This study aimed at showing that Portugal could be one of the European leaders in terms of CSP installed capacity. The study concludes that adding CSP to the energy mix will increase the presence of renewable energy and dispatchability of the overall system while reducing curtailments and associated risks. In addition, the storage system of CSP plants could work to a large extent as an independent infrastructure and be prepared to deliver full nominal power at the peaking demand times. The above topics have been discussed in a series of online meetings with national stakeholders, as a mitigation measure due to the COVID-19 pandemic restrictions.	
NATIONAL EVENT	Phase 3 July 2022
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the development of STE in Portugal. To focus on possible synergies and macro-economic value. Description The joint industry and R&I national event took place on 08 July 2022 in a hybrid format, online via Zoom and in person at the LNEG premises, Lisbon, Portugal. The event included a technical visit to the solar facilities of LNEG. The main conclusions and highlights of the event will be reported in the Deliverable 4.7 "Proceedings of the Joint Industry and R&I Events".	

5.3 Overview of the context in Portugal

5.3.1 R&I landscape

This section presents the main outcome of the background research and the analysis of the information and opinions collected from Portuguese R&I entities involved in CST technologies. It is divided into the financial framework, the ongoing activities of Portuguese R&I entities and the strategies defined in Portugal that have an impact into the focus of research and funding.

5.3.1.1 Funding opportunities for R&I activities in Portugal related to CST technologies

The national funding agency for research activities in Portugal, FCT (Foundation for Science and Technology[88]) is partially supported by the national state budget and by the Portugal 2020 programme. Regularly, FCT opens general calls for scientific research and technological development projects that might be used to fund CST RTD projects, currently with budgets going up to ~250 k€. Both R&D centres and industrial entities can access these funds. However, industrial entities can only access the funds within projects coordinated by R&D centres. The maximum duration of the projects funded by FCT is limited to 36 months and these funds are available only for national projects. FCT also opens applications for PhD and Post-doc fellowships as well as applications to researcher contracts, funding the work of personnel, key to high quality research. In particular, the *Research Infrastructures Roadmap* managed by FCT was a cornerstone in the recent years, giving support to the INIESC (National Infrastructure on Solar Energy Concentration) infrastructure. See section 5.3.1.2 for further information about INIESC.

Although during the last decade R&D funding was managed by FCT through biennial calls, the periodicity foreseen for the next few years is annual. Besides FCT, the already mentioned programme Portugal 2020, was also an important supporter for CST research and development in Portugal at national and regional level through its operational programmes. The Portugal 2020[89] is the partnership agreement adopted between Portugal and the European Commission, which brings together the activities of the five European Structural and Investment Funds - European Regional Development Fund, Cohesion Fund, European Social Fund, European Agricultural Fund for Rural Development and European Fund of Maritime Affairs and Fisheries - which define the programming principles that enshrine the economic, social and territorial development policy to promote, in Portugal, between 2014 and 2020.

With the end of the Portugal 2020 programme, a new partnership agreement between Portugal and the European Commission is being discussed. Energy and climate change will be one of the 8 priorities of the new programme[90]. The new partnership agreement could have some changes in the funding rules. So far, funds from the Portugal 2020 programme have been available for both R&D and industrial entities. However, there have

[88] *See: www.fct.pt*

[89] *See: https://www.portugal2020.pt*

[90] *See : https://www.portugal.gov.pt/pt/gc21/governo/programa/portugal-2030.aspx*

been call-specific limitations that restricted the ability of both type of entities to apply to the same call (e.g., some calls were only for industrial entities, others required both industry and R&D centres participation or project coordination by industrial entities, etc.). The Portugal 2020 calls have been structured within Operational Programmes (OP). The relevant OP for CSP/STE are the regional OP, managed at regional level, the *Competitiveness and Internationalisation OP (COMPETE 2020) and the Sustainability and Efficiency in the Use of Resources OP* (POSEUR), both managed at national level.

Although the maximum duration of the projects funded by Portugal 2020 programme has been typically 36 months, it changed from one call to another (it was call specific). There were no periodic calls, these were only issued from time to time and there have been specific calls supporting the participation of national entities in international projects.

Concerning external funding for CST RTD activities in Portugal, it mainly comes from the European Union Framework Programmes (the current one being the Horizon EUROPE Programme), playing a large role in energy research in Portugal, being the main cross-national funding pillar.

Another recent funding source is the CSP ERA NET[91]. This programme is the result of a joint EU will for bridging the gap between research and commercial deployment in CSP technology, so this technology can play a main role in the European renewable electricity generation in a medium term. CSP ERA NET aims to coordinate the efforts of Member States, Associated Countries and Regions towards achieving CSP SET Plan objectives, by pooling their financial resources to implement joint calls for R&I proposals, resulting on strategic projects with substantial volumes of investment, which cannot be allocated by individual countries or by the European Commission on their own. Portugal is eligible for this funding and is represented in CSP ERA-NET by DGEG[92] and coordinated through The Innovation Support Fund (FAI[93]).

DGEG which is the Portuguese Public Administration body whose mission is to contribute to the design, promotion and evaluation of policies related to energy and geological resources, with a view to sustainable development and guaranteeing the security of the supply. DGEG's mission naturally includes the need to raise citizens' awareness of the importance of those policies, within the framework of the desired economic and social development for the country, informing them of the instruments available for the execution of political decisions and disseminating the results of its monitoring and execution. DGEG is also the Portuguese partner in the programme CSP ERA-NET.

5.3.1.2 Existing R&I activities and infrastructures

Portugal RTD institutions have a well-established background in CST research, both at national and international level.

The main research areas in the CST field in Portugal are:

[91] *See: https://csp-eranet.eu*

[92] *See: http://www.dgeg.gov.pt*

[93] *See: https://www.fai.pt/página-inicial*

- Innovative solar collectors for medium and high temperature operations.
- Standardised methods and experimental testing of solar concentrators.
- Solar energy storage systems (thermal and thermochemical).
- Solar fuels, hydrogen production and other thermochemical applications.
- System integration of solar thermal energy and hybrid systems for desalination, combined heat and power applications, process heat, etc.
- Solar materials and components for CST applications.

The main R&I stakeholders in Portugal are:

- University of Évora, UÉvora[94].
- LNEG[95].
- DGEG, already mentioned in section 5.3.1.1.
- The University of Lisbon, IST[96].
- Science Faculty of the University of Lisbon, FCUL[97].
- The Institute of Computer and Systems Engineering, Research and Development, INESC-ID[98].
- The Institute of Science and Innovation in Mechanical and Industrial Engineering, INEGI[99].
- Engineering Faculty of University of Porto[100], FEUP.
- ISQ[101].
- University of Aveiro[102].
- University of Minho[103].

The main national research infrastructure on CST technologies is INIESC[104], which is included in the Portuguese Roadmap of Research Infrastructures[105] since 2014. INIESC

[94] *See: www.uevora.pt | www.catedraer.pt*
[95] *See: www.lneg.pt*
[96] *See: www.tecnico.ulisboa.pt*
[97] *See: www.ciencias.ulisboa.pt/en/campus-faculty-sciences*
[98] *See: www.inesc-id.pt*
[99] *See: www.inegi.pt*
[100] *See: http://www.fe.up.pt*
[101] *See: www.isq.pt*
[102] *See: www.ua.pt*
[103] *See: www.uminho.pt*
[104] *See: www.en.catedraer.uevora.pt/sobre/iniesc*
[105] *Available in full here:: www.fct.pt/media/docs/Portuguese_Roadmap_Infrastructures2020.pdf*

currently joins the infrastructures of two institutions - UÉvora and LNEG - comprising the most significant expertise and infrastructures available in Portugal in this field; being open for other Portuguese infrastructures to join in the future. Moreover, since both LNEG and UÉvora integrate the consortium developing the implementation of the European Solar Thermal Research Infrastructure for Concentrated Solar Power[106] (EU-SOLARIS[107]), a project included in the 2010 ESFRI Roadmap, this combination of resources from UÉvora and LNEG aims to be the basis for the establishment of the Portuguese node for this European infrastructure.

The establishment of INIESC enabled an ideal framework for the activities already in progress by both partners at computational (modelling and system simulation), laboratorial (materials and solar fuels), infrastructural (solar concentrators testing bench, solar concentrator collector fields with molten salts as HTF and heat storage fluid, technological development of line-focus Fresnel, a solar tower for synthesis of materials and solar chemistry activities, and other concepts) and capacity building (full academic offer) levels. The main scientific objectives of INIESC were focused on the following topics:

- To develop new line-focus and point-focus concentrators addressing specific applications.
- To develop standardisation activities related with thermal energy storage, concentrators testing and concentrator field testing conditions, through new optical and thermal characterisation experimental procedures.
- To assess and demonstrate medium temperature applications (process heat, desalination, cooling, combined heat and power applications).
- To engineer and control solar plants with new concentrators and advanced heat transfer fluids and storage concepts.
- To assess and demonstrate high temperature applications (CSP, solar fuels, waste treatment, new materials).
- To develop and test new materials and components for high temperature applications.
- To propose and study new energy storage (thermal, thermochemical and electric) concepts with different materials and applications in mind.

Relevant facilities of INIESC at its Évora site are Solar Concentrators Testing Platform (PECS) and Évora Molten Salt Platform (EMSP), as shown in Figure 31.

PECS is a platform with the dimensions 18 m x 13 m (234 m2) with a 2-axis tracking system design to test and operate solar concentrating modules up to 380°C, using thermal oil as heat transfer fluid.

EMSP is a full-scale working research CSP Plant (3.6 MWth) with parabolic trough collectors with molten salt as heat transfer medium for high temperatures (560°C).

[106] *See: https://www.esfri.eu/energy*

[107] *See: http://www.eusolaris.eu/*

(a)

(b)

Figure 31: INIESC testing platforms (Évora site): (a) PECS platform; (b) EMSP platform

Relevant facilities of INIESC at its Lisbon site (LNEG) include a solar tower (STTF100 - Solar Tower Testing Facility 100), a Fresnel lens Furnace (FF-1), the Solar Energy Laboratory (LES), the Material Characterisation and Durability facilities (MCD), a Fuel Cells and Hydrogen facility (H_2) and a High-Performance Computing facility (HPC).

The STTF100 facility is a 100 kWth solar tower currently under development at LNEG that will have a solar field of 220 m^2 and a 14 m height tower with three platforms for the development of experiments.

FF-1 is a Fresnel lens concentrator (Figure 32) with 0,75 kW and peak flux on target up to 2400 kW/m^2 used equipped with a cylindrical reaction chamber for inert atmospheres with 250 mm of diameter and 150 mm height.

(a)

(b)

Figure 32: Fresnel lens solar furnace

Solar Energy Laboratory focuses on Solar Thermal Systems and its components, testing Solar Thermal Collectors according to ISO 9806, Factory Made Systems according to EN 12976 and Hot water storage tanks according to EN 12977. It also provides optical characterisation services for collector components (e.g., absorbers or reflectors) through spectrophotometer analysis.

Material Characterisation and Durability facilities aggregate several laboratorial and outdoor facilities for advanced material analysis and characterisation (including molten salts) and for materials' durability, corrosion and anticorrosive protection (Figure 33).

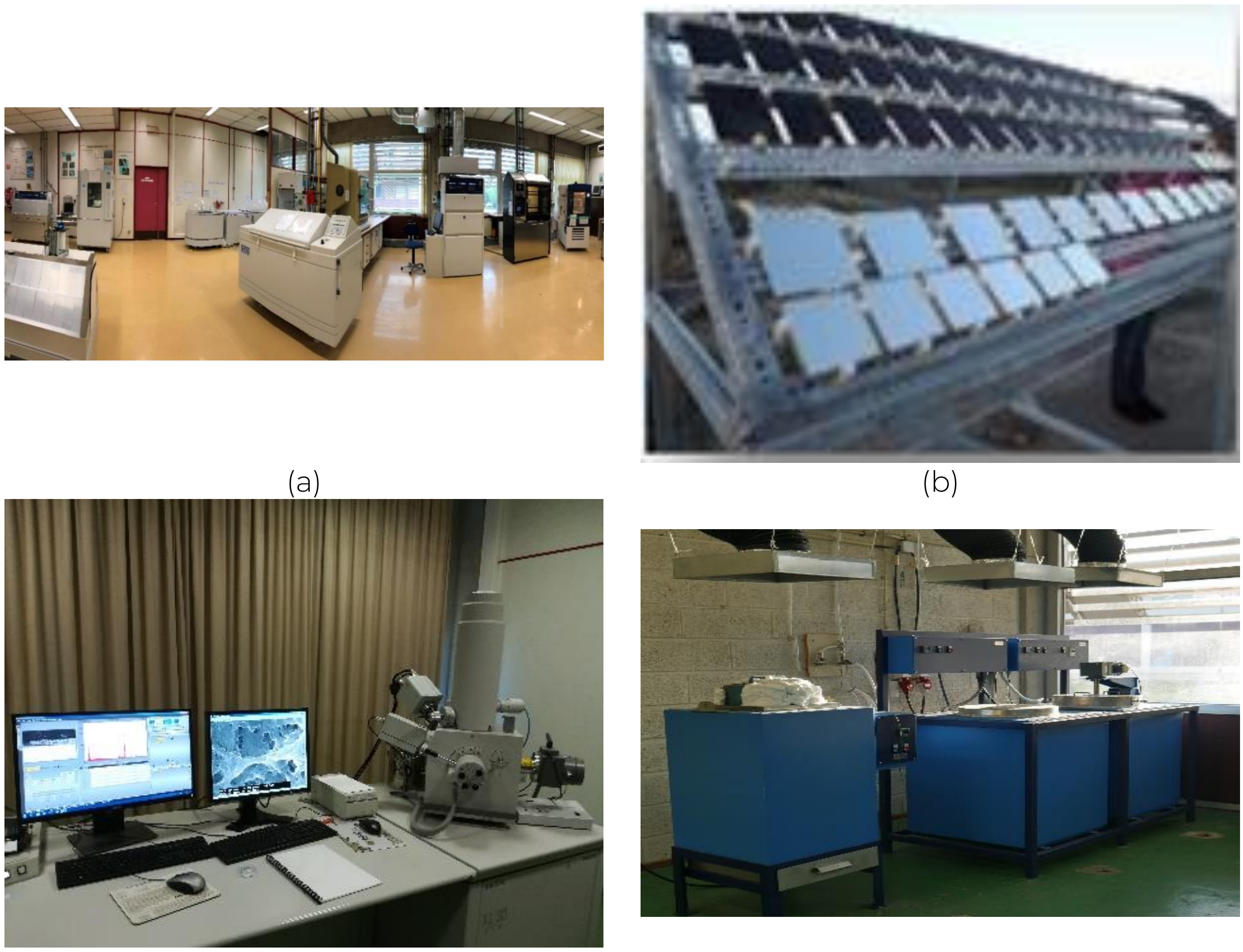

Figure 33: Material characterisation and durability facilities: a) Climate cabinets for the accelerated ageing tests; b) Outdoor exposure testing; c) Scanning electron microscope; d) Crucible salt bath furnaces

Apart from this, other national institutions also have facilities that can be used for CST R&I activities, namely:

- Instituto Superior Técnico (Lisbon).
- Faculdade de Engenharia da Universidade do Porto (Porto).
- University of Aveiro (Aveiro).
- Faculdade de Ciências da Universidade de Lisboa (Lisbon).

- Cenimat of Universidade Nova de Lisboa[108].

The contributions of Portugal to the SET IP have been at both national and European level. Outstanding research infrastructures have been established and funded through such projects. The key data of these projects (starting on September 2017) is shown on below.

[108] *See: www.cenimat.fct.unl.pt*

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Portuguese Industrial Partners	Portuguese R&D Partners
N	LIFESOLAR - Service life of key components for solar thermal energy applications	Lifesolar	LNEG	2016-2020	OPENPLUS, MCG, HEMPEL	LNEG, FCT (UNovaLisboa)
N	Infra-estrutura Nacional de Investigação em Energia Solar de Concentração	INIESC	UÉvora	2016-2020	----	LNEG, UÉvora
N	Low-emissions system towards green fuels and high added-value bioactive compounds production based on Gordonia alkanivorans strain 1B biorefinery	GreenFuel	LNEG	2018-2021	----	LNEG

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Portuguese Industrial Partners	Portuguese R&D Partners
EU/N	Fomento de tecnologías innovadoras para la mejora de la eficiencia en el proceso de secado de los lodos de Aguas Residuales y de secado de Residuos Sólidos Urbanos mediante el uso de Tecnologías Solares en Andalucía-Algarve-Alentejo	SECASOL	Dip. Huelva	2017-2020	Aguas do ALGARVE, GESAMB, AREAL	LNEG
EU	Integrating National Research Agendas on Solar Heat for Industrial Processes	INSHIP	Fraunhofer ISE	2017-2020	---	LNEG, UÉVORA, IST-ID
EU	New StOrage Latent and sensible concept	NewSOL	UÉvora	2017-2020	SECIL	LNEG, UÉVORA

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Portuguese Industrial Partners	Portuguese R&D Partners
	for high efficient CSP Plants					
EU	Biofuels Research Infrastructure for Sharing Knowledge II	BRISK2	KUNGLIGA TEKNISKA HOEGSKOLAN	2017-2022	---	LNEG
EU	Solar Facilities for the European Research Area - Third Phase	SFERA-III	CIEMAT	2019-2022	---	LNEG, UÉvora
EU	Integrated Catalytic Recycling of Plastic Residues Into Added-Value Chemicals	i-CAREPLAST	CSIC	2018-2022	---	LNEG
N	High Performance Solar 2	HPS-2	DLR	2014-2020	---	UÉvora
N	Instalação, ensaio e análise de um concentrador Advanced Linear Fresnel Reflector para a produção de electricidade	ALFR-Alentejo	UÉVORA	2019-2022	---	UÉvora

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Portuguese Industrial Partners	Portuguese R&D Partners
	por via termosolar com armazenamento térmico					
EU	European Parabolic Trough with Molten Salt	EuroPatMoS	DLR	2020-2023	---	UÉvora

R&D Projects with involvement of Portugal relevant to the SET IP (only those projects ending in 2020 or later have been included)

5.3.1.3 Overview of involvement in research projects

The UÉvora is currently the most active entity in terms of involvement in projects on concentrated solar thermal technologies (Table 26).

Project name	Description
ALFR Patent	Patent Application for Advanced Linear Fresnel Reflector Solar Concentrator. The main objective of this project is to support European Patent Application Nr. 3524901: "Compact Linear Fresnel Reflective Solar Concentrator Design for Direct Molten Salt Operation as Heat Transfer Fluid in Evacuated Tubes". The project includes material and financial support for the costs inherent to the patent application, with Portugal 2020 funding.
ALFR-Alentejo	Installation, testing and analysis of an Advanced Linear Fresnel Reflector concentrator for the production of electricity via thermosolar with thermal storage. The objective of this project is to implement the modelling, installation, testing and analysis of a prototype solar concentrator ALFR (Advanced Linear Fresnel Reflector) for the production of electricity via thermosolar and couple it to thermal storage systems with mixtures of molten salts, in order to operate at temperatures above 500°C, and to increase the conversion efficiency of solar energy. The project is implemented in conjunction with the EMSP and PECS platforms, and the INIESC research infrastructure.
HPS2	High Performance Solar 2 This project aims to analyse the efficiency and reliability of parabolic plants with molten salt as a means of heat transfer at high temperatures, replacing the use of thermal oil as a mode of heat transfer generated by solar radiation. Molten salts have advantages over the level of lower costs and heating potential at higher maximum temperatures (up to 560°). The testing is implemented on the EMSP platform.
NEWSOL	New Storage Latent and sensible concept for high efficient CSP Plants. It is a project whose main objective is to develop innovative thermal energy storage solutions, using new functional and advanced materials, with thermal fluids, sensitive storage media and insulating materials, in two concepts of single tank storage with thermocline separation and concrete modules. It also includes the validation of the performance of different types of materials.
SFERA-III	Solar Facilities for the European Research Area – Third Phase. SFERA-III seeks to continue the SFERA I and SFERA II projects, and to strengthen the sustainability of European research infrastructure activities in the area of advanced concentrated solar energy. It includes networking and cooperation between research infrastructures, the scientific community, industry, and other

Project name	Description
	stakeholders; transnational activities for European researchers; and joint research activities.
Solar Tech	Transferência de Tecnologia e Conhecimento em Energia Solar e Armazenamento de Energia. This project aimed to transfer technology and knowledge to the business sector, focused on the application of three major technological lines: solar photovoltaic associated with high-power pumping or irrigation systems; solar thermal for process heat in industry; and photovoltaic for residential energy and services, using advanced batteries, with intelligent management and integration.

Table 26: STE R&I activities in Portugal

5.3.1.4 Existing active networks

There are two main structures in Portugal which are dealing with STE activities: LNEG and DGEG.

LNEG is a government organisation, independent in its work, which supports public policy through studies and projects. During an interview, LNEG told ESTELA that its field of research is close to the market. It carries out research on various areas, including solar thermal technologies. In this regard, LNEG:

- Explores the role of solar for industrial applications and high temperature applications.
- Is interested in the thermo-chemical aspect of CSP, which might play a role as input for renewable gases and storage around 2050, in particular for the production of hydrogen, which is regarded as a major future player.
- Possible connection between bioenergy and solar energy might be a future area of exploration. The bioenergy sector is an important sector in Portugal, especially because of the forest issue (*i.e.*, the forest fires), which cause political concern.
- Since recently, and in cooperation with UÉvora, has started exploring the complementarity between CSP and PV for a same injection point.
- Focuses on the question of the integration of renewables to the system, particularly since the Portuguese government decided to close the coal power stations.
- Is considering the topic of storage as an important point of focus.
- Also carries out resource analysis, direct normal irradiation analysis, and works on the topic of materials.

The second main actor, DGEG, is the entity giving the permits to build power plants. It gives the possibility to build pilot projects through different calls, be them EU or national programmes. It is thereby involved in various networks for STE:

- The energy transition partnership.
- Some steering groups of the SET-Plan.
- CSP-ERANET.

The research unit which ESTELA interviewed established the scenarios in the National Energy and Climate Plan (NECP) and ensured us that there is a real motivation to introduce CSP in Portugal. DGEG is supporting a pilot project planned for 113MW towards 2025, which would help reach the 300MW announced in the NECP by 2030. At the moment, it focuses more on licensing projects for hydrogen generation, using CSP trackers to produce and TES to store hydrogen.

Some companies are also developing their own R&I activities, in particular Energias de Portugal (EDP) and GALP. However, none of them has an STE department. These companies usually team up with universities to benefit from national funding programmes.

5.3.1.5 Financing frameworks

Research programmes are largely funded by the government and the EU. There are incentives for research and projects on innovation and technological development in the field of renewable energy. The campaign to disseminate information on RES covers solar, PV, wind, biomass, geothermal, and tidal energy. FAI was established aiming to promote research and projects of innovation and technological development, primarily in the field of renewable energy. In 2010 it was extended to the energy efficiency sector. In order to be eligible for FAI, the project must be related to one of the strategic areas such as scientific and technological research, seminars or conferences; Ph.D. or master researches as well as institutional campaigns to raise awareness with a focus on renewable energy and energy efficiency. The evaluation of renewable energy projects to be submitted to FAI has been suspended.

5.3.2 Overview of the context for industry

The desk research and the preliminary interviews helped ESTELA refine its understanding of the energy context in Portugal. The following subsections were enriched thanks to ESTELA's own desk research and inputs from three stakeholders: APREN, TSO (REN) and LNEG. The latter has been very helpful, providing the consortium with a list of stakeholders to contact and sketching out a thorough context of energy policy in Portugal.

5.3.2.1 Energy policies and the place of STE in the Portuguese landscape

5.3.2.1.1 Current energy mix in Portugal

Portugal's primary energy consumption still mainly relies on fossil fuels (around 60%), as shown in Figure 34, with petroleum products representing more than a third of the total primary consumption. Portugal is therefore planning to massively electrify its energy consumption to decarbonise it, aiming to meet more than 60% of its final energy consumption by electricity.

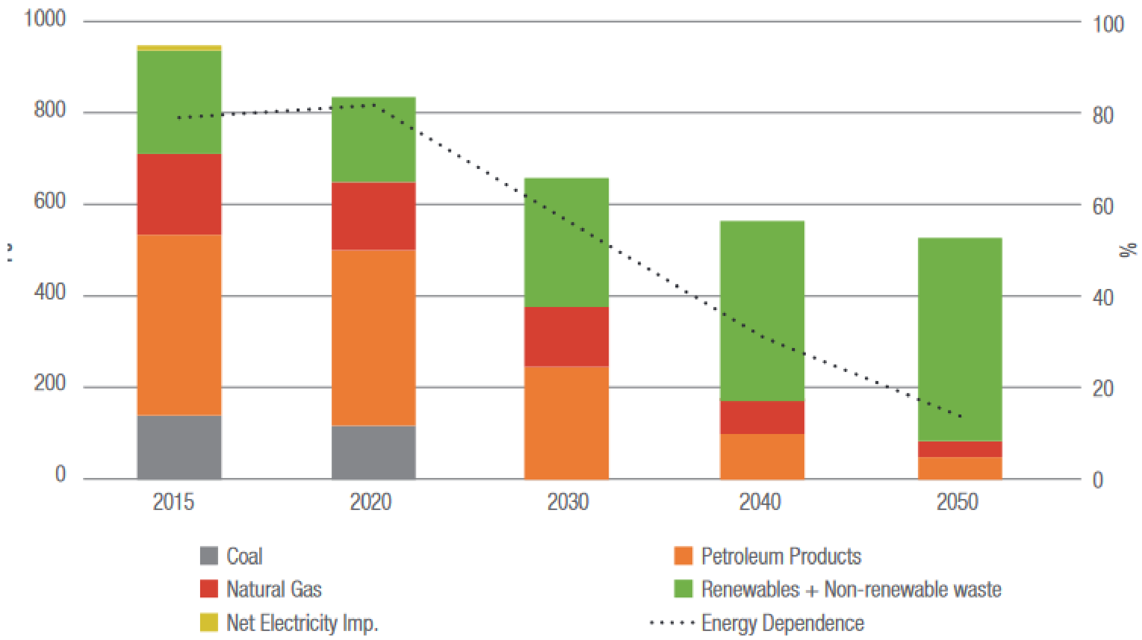

Figure 34: Primary energy consumption in Portugal (2015 - 2050)

In the power sector in 2019 renewables represent 51% of the generation[109], as shown in Figure 35. In 2019, Portugal had 20,208 MW of installed capacity, whose composition is detailed in Table 27[110].

Category	Installed capacity (MW)
Renewable	13,847
Hydro	7,216
Wind	5,208
Biomass	693
Solar (PV)	730
Non-renewable	6,361

[109] *Available in full here: https://www.ren.pt/files/2020-03/2020-03-18181207_f7664ca7-3a1a-4b25-9f46-2056eef44c33$$72f445d4-8e31-416a-bd01-d7b980134d0f$$ebb69f10-6bdf-42e0-bcc4-a449cddf60ca$$storage_image$$pt$$1.pdf*

[110] *Ibid.*

Category	Installed capacity (MW)
Coal	1,756
Natural gas	4,597
Others	8
Total	20,208

Table 27: Installed capacity as of 2019

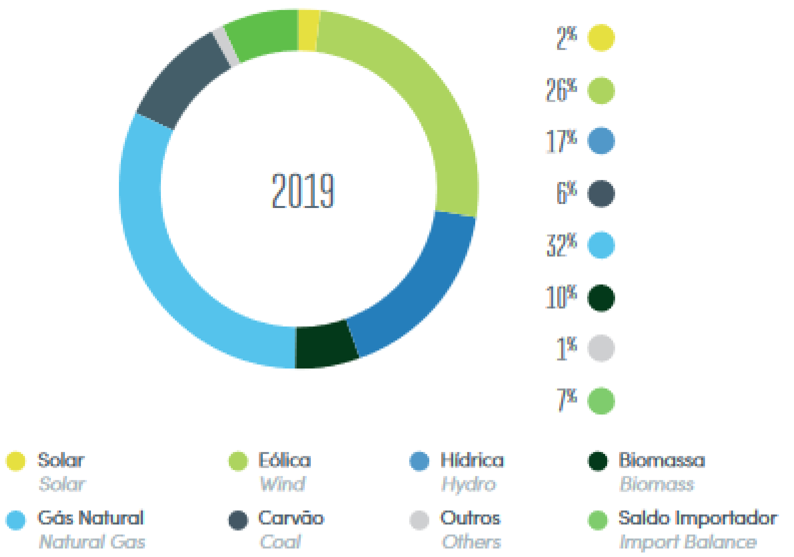

Figure 35: Electricity generation in 2019

According to LNEG, Portugal aims to reach a total installed capacity of around 30,000 MW by 2030, achieving 9,000 MW of PV and 9,300 MW of wind. With its ambitious target of 80% of renewables by 2030, Portugal will face a storage challenge, as confirmed by REN.

The Roadmap for Carbon Neutrality 2050 (RCN2050) published by the Ministry of Environment and Energy Transition, gives an overview of the expected challenges and paths to be taken by the country to meet its targets. Amongst them, elements regarding generation capacity will have a tangible impact on the Portuguese energy mix:

- The end of coal-fired power production by 2029.
- The end of gas-fired power production from 2040.
- The decrease by 4% of power generation from hydro without pumping in 2040, compared to 2020, because of water scarcity.
- By 2040, battery storage will represent 3 to 4% of the total installed capacity.
- By 2050, it will represent 6%.

In electricity generation, the transition is expected to be facilitated "by the reduction in the cost of renewable-based technologies for electricity generation that has been observed in recent years, especially in technologies associated with solar photovoltaics"[111]. This opens the door for hybridisation projects between STE and PV, which would contribute to accelerate the decarbonisation of the power system. Portugal plans to keep natural gas in its generation mix until 2040 to facilitate the transition. However, the development of STE plants could favour an earlier phasing out of the gas plants. The RCN2050 also expects rapid falls in the cost of storage solutions. This would also work in favour of STE with TES. These two elements are part of the necessary conditions for Portugal to reach almost 100% renewables in its electricity production by 2050.

The use of batteries and the role they could play remains still hypothetical and relies on "hoped-for" developments, as their capacity should reach 4 GW by 2050[112]. Being an already proven technology, TES could bring a bigger added value, in particular as solar PV capacity is expected to be multiplied by at least 7 by 2030.

Hydrogen is seen as one of the potential new energy vectors to be developed, in particular in hard-to-abate sectors such as transport. The RCN2050 foresees that, by 2050, 5 to 8% of the produced electricity will be used to generate hydrogen[113]. This is an interesting argument for the construction of STE plants in Portugal, given the potential of the technology to contribute to generate hydrogen, thanks to its high temperature capacity. Portugal aims to reach 35% of renewables in the transport sector by 2030, 60% in 2040 and 90% by 2050[114]. This will require an important production of green fuels, in which STE could participate.

Regarding industry, challenges are almost as high as for the transport sector, in particular for industrial processes for sectors such as the mineral and chemical industries. Portugal plans to reach a 72% of emission reduction by 2050, partially through electrification. Heat generation is foreseen to be covered by renewable co-generation for high temperature and solar heating for low/medium temperature.

The acknowledgement of the challenge represented by high temperature heat could also be explored with CST technologies solutions, as the adjunction of TES to some existing centrals can increase energy efficiency of the processes. In addition, as Portugal foresees an increase in the share of natural gas in industrial processes until 2030 and a progressive decrease afterwards, the hybridisation capacity of TES with gas could accelerate the decarbonisation process.

5.3.2.1.2 The Portuguese NECP and the potential for STE

Portugal aims to decrease its greenhouse gas emissions by 60% and increase the share of renewable energies up to 80% in its electricity generation by 2030.

The Portuguese NECP is one of the four NECPs mentioning the use of STE for electricity generation, with 300 MW of new installed capacity foreseen by 2030. As a first step, 100

[111] *Available in full here: https://www.ren.pt/files/2020-03/2020-03-18181207_f7664ca7-3a1a-4b25-9f46-2056eef44c33$$72f445d4-8e31-416a-bd01-d7b980134d0f$$ebb69f10-6bdf-42e0-bcc4-a449cddf60ca$$storage_image$$pt$$1.pdf*

[112] *Ibid.*

[113] *Ibid.*

[114] *Ibid.*

MW are already expected by 2025. In this regard, the Portuguese government carried out a competitive procedure for 700 MW of solar energy in the third quarter of 2020, with the positive introduction of mechanisms to remunerate capacity and to consider solar technologies with and without storage (STE included). If CSP projects would have been awarded, it would have been an important step in the reactivation of the sector in Europe and also a first step towards this projected installed capacity.

During the discussion with LNEG, the question of the considerations about the complementarity between PV and STE was mentioned. Even though it has not been studied so far in the country, the new perspectives introduced by the NECP led them to start a new cooperation with the UÉvora, to have a first study on complementarity, with CSP and PV for a same injection point, in preparation of the Iberian and Latin American Solar Energy Conference in Autumn 2020.

As a summary, the current Portuguese energy policies may open the door for further CST technologies penetration in the energy mix, be it for electricity generation, energy storage or the decarbonisation of hard-to-abate sectors. The hybridisation characteristics of CST puts it as a strategic element for the future Portuguese energy mix. The outcome of the solar tender in August will weight on the potential future development of the technology in the country.

5.3.2.1.3 Study on the potential of CSP in Portugal

In 2020 ESTELA commissioned to Protermosolar a study about the potential of CSP in the electricity system of Portugal until 2030 using Inductive Projection Planning (IPP). The objective of the study was primarily to support Portugal's decision to include 300 MW in their NECP. Further the study should propose new perspectives on the role and the impact of the amount of CSP capacity to be introduced in the Portuguese electricity system. The study aimed at assessing if Portugal could be one of the European leaders in terms of CSP installed capacity.

The main technical conclusion of the study was to place the optimal effect of new CSP capacity to be installed until 2030 at a recommended range between 1.2-2 GW, i.e. beyond the planned 300 MW of the Portuguese NECP resulting in a electricity mix with lower and manageable curtailments (reduction between 50% and 80% compared to the NECP) while keeping virtually the same overall system cost.

Adding more CSP will foster the deployment of higher variable RES capacity as their merchant prices would remain attractive since curtailments would be dramatically reduced and without further support from the government.

In addition to the above, a high penetration rate of CSP would avoid further investments in grid stability equipment, since CSP provides reliable synchronous power. This additional synchronous power would be a complement to hydro power, reducing the dependence on natural gas combined cycles. The complementarity of hydro (for wet years) and CSP (for dry and sunny ones) appears as the best renewable strategy to replace the use of fossil fuels in Portugal.

Finally, the study concluded that the storage system of CSP plants could work – to a large extent – as an independent infrastructure and be able to deliver full nominal power at peak demand times, independently on whether the previous days would have been sunny or not, even in wintertime. The value of such services – strategic reserve, use of curtailed energy, price arbitration. balancing, etc, – that can be provided by the storage system of the CSP plants – with zero or much lower investments compared to batteries or new pumping stations – are additional reasons to recommend a higher share of CSP in the Portuguese electricity mix.

5.3.2.1.4 General approach to a socio-economic impact of CSP in Portugal

To prepare meetings with Portuguese officials, ESTELA received the help of LNEG to project potential benefits from the development of CSP in Portugal. In this regard, LNEG carried out a preparatory study to highlight the possible direct and indirect jobs which would be created if CSP would unfold in the country. The projection is based on the Spanish employment factor, since the labour and economic structures are similar between the two countries. As can be seen in Table 28, the estimated number of direct and indirect jobs which could be induced by CSP in Portugal would be of 3,840, in 2030 only.

Potential created direct jobs in Portugal with CSP	2025	2030
Installed foreseen capacity of CSP as in PNEC 2030 (MW)	*100*	*300*
Installation & construction jobs	1200	3600
O&M jobs	80	240
TOTAL jobs	**1280**	**3840**
Jobs / MW	*12.8*	*12.8*

Table 28: Estimate of potential job creation in Portugal with CSP deployment (LNEG model)

The initial Portuguese approach of renewable energies has been focusing on wind power technologies. In its exploratory note, LNEG underlines that wind technology has benefited from a cluster of development strategy which allowed the country to develop national manufacturing of rotor blades, tower structures, nacelle and generator components, and O&M services. On annual average, RES technologies generated in Portugal around 41,000 jobs between 2014 and 2018. Together with hydro, wind power represented 82% of those jobs.

However, this dynamic trend of wind will be slowed down by the development of solar PV in Portugal, which generates more jobs per installed MW than any other RES technology. According to the exploratory assessment from LNEG, solar PV represents 10 jobs per installed MW, while wind only represents 4 jobs/MW. Between 2018 and 2030, RES technologies are expected to generate 114,000 jobs on annual average, 63% of which would be represented by PV.

In comparison, based on the Spanish employment factor, CSP would represent around 12 person per year per MW for construction and 0.9 person per year per MW for O&M services. Even though this does not seem to weight much, the advantage of deploying CSP in Portugal comes from the ideal locations for the technology the Alentejo and Algarve regions. Since these are rural areas with fewer economic opportunities, the installation of CSP plants in those regions would represent non-negligible local employment opportunities.

If LNEG's exploratory assessment sees limited opportunities for the deployment of CST at the moment, given the preference for other technologies, there is a potential to deploy CSP in Portugal and generate socio-economic benefits for the country.

5.3.2.2 Energy regulation in Portugal: a strategy to include flexibility

Sector integration is of primary concern for ERSE to achieve higher decarbonisation, decentralisation, and digitalisation. ERSE has identified five strategic orientations for the period 2019-2022, which can be seen in Figure 36 below. In its Strategic Plan for the same period, the regulator sees four main challenges, for which STE, and CST technologies at large, could bring solutions:

- Sector integration.
- Energy storage in batteries or renewable gases.
- Solutions of greater importance. flexibility in system management.
- Optimisation of cross-border interconnections will also contribute to this end and to greater competition and security of supply in general.[115]

Flexibility is really a challenge which ERSE is aware of, while also considering it as an opportunity for further integration of renewable production in the system and an alternative to new networks. According to ERSE, "the sources of this flexibility will be multiple, and it will be up to the market to determine its viability"[116].

To ensure a fair remuneration of the flexible characteristic, ERSE plans to focus on the framework of regulatory incentives to "ensure a greater diversity of resources for the provision of flexibility, mitigating the usual logic that makes the provision of this type of services based on traditional agents in the sector". However, as a regulator, ERSE remains technology neutral. In addition, tenders are organised by the government, which gives the regulator a limited role in this area.

Amongst other solutions, ERSE considers the complementarity between renewable production and hydroelectric plants with pumping capacity as a good possibility to increase flexibility. However, as ERSE must regulate the electricity, natural gas, liquefied petroleum gas, oil derivatives fuels and biofuels sectors, it must take into account market's characteristics. Even if some RES are today competitive, the wholesale market price level is the most relevant criteria (signal) for new investments in generation. By supporting a balanced portfolio of solutions including renewable production, flexibility resources (including storage) and consumption, ERSE would make market players more competitive and decrease the risks they take. ERSE is therefore fully aware of the importance of regulatory models to be adapted to the redesign of a market model which can face these upcoming challenges.

If gas is also considered as a "backup" when renewables cannot deliver and to be a guarantee for system flexibility, discussing the potential of CST with ERSE might bring

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[115] *Available in full here: https://www.erse.pt/media/akvhixai/plano-estrategico_2019-2022_.pdf*

[116] *Ibid.*

further information on the table and show the regulator that the upcoming challenges Portugal is facing can be mainly solved through renewable solutions.

These first elements are paving the way for interesting discussions between ERSE and the HORIZON-STE consortium. There is *a priori* no obstacle for STE to enter the Portuguese energy market, and the awareness of the role of flexibility, especially storage, appears as favourable for STE.

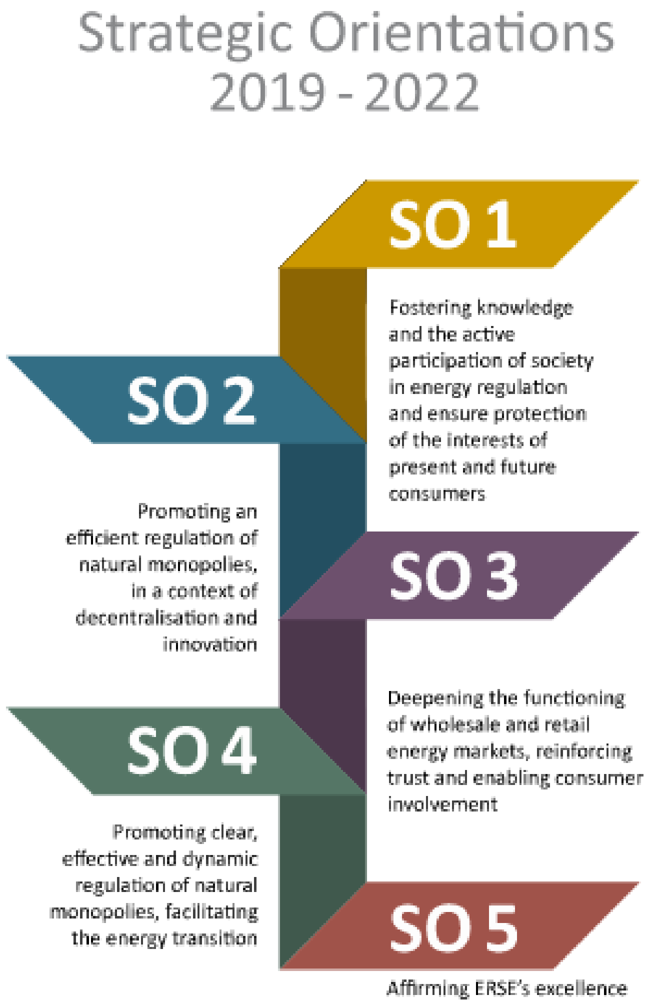


Figure 36:ERSE's Strategic Orientations (2019-2022)

5.3.2.3 The energy transmission system in Portugal: the role of REN

ESTELA had an interview with employees from REN, the Portuguese TSO, respectively involved in Network Planning, Studies and Regulations, and Grid Connections.

An important aspect of the Portuguese grid relies on its interconnections with Spain, as can be seen in Table 29. It is planned to reinforce the transfer capacity in the upcoming decade, in particular with a new high voltage line, which should be operational in 2022, in the North of Portugal, even though difficulties are experienced in this zone.

Transfer capacity	2019 (average)	2030
Import	2.6 GW	4.2 GW
Export	3.3 GW	3.6 GW

Table 29: Net transfer capacity between Portugal and Spain

Currently, the main production from renewables comes from hydro and wind, which are located in the central and northern parts of Portugal. PV, and potentially STE, will always be located in the Southern part of the country. However, there is an asymmetry between the consumption of energy in the South and North, as the biggest cities are located in the North of the country. This means that the transit of energy from South to North would need to be increased if more PV and STE would be installed in the South.

A new law introduced in June 2019 related to grid connection conditions opens now three different options:

- Promoters can submit new RES projects via the government's website to increase network capacity. Requests are then forwarded to TSO if > 50 MVA, to the Distribution System Operator (DSO) for projects <50MVA. This option was so successful that after 1.5 months, no more capacity could be allocated in transmission network, since all the available transfer capacity had already been placed.
- New auctions to be introduced by the government:
- In July 2019, the first auction took place for 1.4GW of PV, without any obligation to provide solutions for storage. 1 GW were requested at TSO level, 0.3GW at DSO level, 0.1GW was not auctioned, as the auction lot was without competitors. The reference tariff offered was of €45/MWh. The cheapest bid received was of €15/MWh, the average bid was of €21/MWh.
- The second auction will take place on 24-25 August 2020 and will value solutions regarding storage and therefore consider a variety of solutions, *e.g.*, PV plant / PV + battery / CSP plant / PV+CSP hybridisation. 700MVA will be auctioned[117].
- A direct agreement between promoters and REN can be established when REN has not enough internal transmission capacity. In this case, such internal reinforcements are paid by promoters, thus allowing new capacity. Hundreds of requests were received. The rationale for taking such additional cost is to allow connections of RES projects in places, quantities or times not considered in the national development plan for transmission network, accelerating the contribution to reach renewables targets.

During the meeting, the future of storage in Portugal was also discussed. Pumped hydro has a very good potential in the country, with approximately 2.7GW installed capacity today and 3.6 GW planned by 2023. It is expected, according to REN, to play an increasing role for managing the security of the whole system, also optimising possibilities with Spain. In particular, its use for seasonal storage and the possible variation of the pump mode from 70 to 100% is praised by TSO. However, REN is not opposed to the use of STE and TES as a storage solution and to also solve the problem of inertia. The only

[117] *See: https://www.portugalenergia.pt/*

problematic would remain the question of owning the storage capacity, as the EU currently does not allow TSO to own storage connected to the grid

Since the first discussion with REN brought positive results and seemed to open the door to STE plants, a new call to discuss the decommissioning of old coal power plants (by 2030) and the extended possibilities to use TES is to be scheduled in the next months.

5.3.2.4 STE as a potential industry driver in Portugal

During the meeting with LNEG, the link between industry and research was mentioned. The topic of storage is an important one on the research side. LNEG has, for instance, been interested in the connection between bioenergy and solar energy. Regarding the industry side, there are some PV factories in Portugal but, what could be very interesting, is to show the possibilities for the Portuguese metallurgy industry to collaborate in the process of STE installations for instance. The glass industry would also be very interested in being involved in STE planning, according to LNEG.

If currently no Portuguese company is involved in STE projects, the solar tender including STE may create new perspectives for businesses to develop. In addition to the existing Portuguese areas of excellence, such as in metallurgy or glass, the development of STE could also bring a new dynamic to these sectors.

However, this may only happen if STE can integrate the portfolio of major Portuguese energy players, such as EDP, and be recognised for the assets it can bring. At the moment, the technology is not considered as competitive enough, compared to the costs of wind and PV which are drastically low. As long as storage and flexibility are not an issue, the involvement of industries in STE will remain limited.

5.4 Key findings

No opposition to the deployment of STE in Portugal has been faced in the contacts established by ESTELA with different stakeholders. Some R&I activities are even ongoing, not only showing interest but also expertise in the sector. In addition, ESTELA encountered a genuine interest from part of the different actors and could easily receive positive answers for interviews.

5.4.1 R&I

5.4.1.1 Portugal does not have a strong and sustainable R&I support programme

It has been explained in section 5.3.1.1 that the national funding sources for R&I activities in Portugal related to CST technologies are the national funding agency for research activities, FCT and the Portugal 2020 programme. However, these funding sources need to consider specific targets for funding CST research and demonstration projects beyond the 2020 horizon. A similar necessity exists at policy level, in the national plans regarding energy efficiency and renewable energy deployment, which should also commit with specific targets regarding renewable energy deployment in industries, including specific targets for solar thermal energy penetration in the industrial sector.

Also crucial is the availability of stable funding for national research infrastructures supporting its maintenance and further developments. In particular, a second phase of INIESC project should be envisioned and funded as this will be the cornerstone of the main R&I activities in the CST field in Portugal.

Furthermore, it is also necessary to ensure the alignment of the national funding programmes priorities with the European priorities (SET-Plan and HORIZON EUROPE Programme). For CST this corresponds to highlight this area as a relevant sector.

5.4.1.2 A significant improvement in R&I know-how and facilities in recent years

The strong involvement of Portuguese R&I entities in European and national projects related to CST technologies have significantly improved their know-how and capacities. The experimental facilities implemented in Évora in recent years, together with a good level of direct solar radiation, make Portugal a country that can play a significant role in the development of many objectives of those defined in the updated Implementation Plan for CSP. Simulation and modelling capacities, together with a set of laboratories and the outdoor facilities available at UÉvora provide an excellent background that must be taken into consideration when looking for R&I partners in international projects.

5.4.2 Industry

5.4.2.1 The Portuguese R&I is closely linked to the government's policy strategy

R&I projects in Portugal are clearly and logically supporting the decarbonisation goals of the country. This encompasses not only the electricity aspects, but also the industry heat, as shows the Solar Tech project, carried by UÉvora.

The specific roles of LNEG and DGEG are however the main drivers of this close adequacy between R&I activities and political strategies. As a government organisation, LNEG is thus in a position of at the same time following and also driving the Portuguese energy strategy. In this regard, the focus on solar for industrial applications and high temperature applications, as well as the interest in the thermo-chemical aspect of STE for the production of hydrogen are thoroughly in line with the Portuguese government's priorities.

In addition, the participation of DGEG to networks such as CSP-ERANET or some Set-PLAN steering groups also shows the interest of the Portuguese authorities in the technology. During a meeting, DGEG also confirmed its interest in CSP through the support it brings to a pilot project of 113MW towards 2025 and in licensing projects for H_2 generation. One of these projects consists in a 1MW CSP plant to produce hydrogen, with 50 trackers and 300kW storage and interconnection to the grid, in addition to the Crystalline silicon photovoltaic projects.

5.4.2.2 System integration is the current priority to achieve a high decarbonisation and decentralisation

Hydrogen production, in particular with concentrated PV to produce hydrogen on local basis and at very low costs, would also help decentralise energy production. Hydrogen would also be used by EDP for heat purposes, the company not considering thermal storage as a match in the near future.

However, Portugal remains open to other technologies, not only through ongoing research on hydrogen, hand in hand with the industry sector, but also on other technologies. UÉvora and the Solar Tech project are highly focusing on system integration, including the role of solar thermal for process heat in industry.

Solar is still underrepresented in the Portuguese energy mix, but the NECP plans to drastically increase its share, including through hybridisation. EDP has up to date made most of its renewable investments in onshore wind, as it is cheapest, with high feed-in-tariff and has economically more advantages than PV. However, it is also developing different strategies to further decarbonise the Portuguese energy system. For instance, the energy provider has already experimented combination of PV and hydro through a 4MW project, or floating PV on hydro dams. EDP also plans to further invest in wind, which is already well established in the country. Like PV, wind must cope with strong restrictions due to grid capacity. Two options exist then: hybridisation to increase flexibility, or repowering/overequipping some injection points. This may involve new turbines which can better deliver or the oversizing of the generation unit.

Portugal also considers integrating natural gas when it is needed. This means, according to ERSE, the regulator, that Portugal needs to make natural gas infrastructures fitting renewable gases and hydrogen perspectives. In this regard, ERSE is pushing for improving the existing interconnections, which are already considered as very good with Spain, despite a long delay in North/Galicia. However, being an island in the perspective of Iberia could hinder a good sector integration, hence the will to reinforce the interconnections between Iberia and France. Being integral part of bigger targets would benefit Portugal.

In addition, sector integration would also benefit a higher decentralisation and help embrace the logic of circular economic, to maintain the competitiveness while supporting decentralisation, which already started attracting investors' interest.

5.4.2.3 The existing Portuguese activities in the field of STE could pave the way for further STE in the country on the long-term

Currently, short-term decarbonisation is the priority. There is presently no real need to balance the electricity system in Portugal, nor for green balancing of the energy, as pump hydro plays this role perfectly. As mentioned by EDP and actors from the Ministries and the Regulator, the market is driving the choice of technologies. The costs are determining the speed at which one technology will develop and be taken up by investors. At the moment, in Portugal, wind, hydro, and soon PV, are the preference for electricity generation.

However, the door is not closed to CSP. The ongoing research and projects could help prove the use and reliability of STE, especially regarding storage and hydrogen. The timing is just currently not the right one. There were already CSP pilot projects since 2010 in Portugal, even though they were put aside for "technical and political reasons", according to the Secretariat of State for Energy. Yet, the Portuguese NECP states that 300MW of CSP would be built by 2030, which shows a renewed positive approach to the technology and consideration from policy makers. The talk ESTELA had with the Directorate General for Energy and Geology confirmed that the country is looking into STE and sees potential benefits in the technology.

The existence of opportunities for STE in Portugal has also been acknowledged by both LNEG and REN, not only to increase the electricity production but also to contribute to the flexibility of the system. Research is ongoing regarding the question of storage. LNEG underlined the use of CSP to also allow a further penetration of PV in the Portuguese energy mix. REN is also looking for solutions, beyond pump hydro, to increase system flexibility. Even though TSO acknowledged the benefits of CSP + storage to solve the problem of inertia, the natural Portuguese hydro resources make it a favourite solution for storage, in particular seasonal storage. Current hydro plants could have a pump storage solution added, to increase the security of the whole system and optimise possibilities of exchanges with Spain.

On its side, the Regulator, ERSE, is preparing a new regulatory period in 2022 for three years. This implies that it will issue consultations in 2021 on various topics to prepare the 2022 period. Amongst others, the role of storage if it is connected to a plant, or if a plant only built for storage, the role of self-generation, will probably be looked at.

In addition, a potential fringe of the Portuguese industry could benefit from the development of STE plants in Portugal, in particular the metallurgy, glass, and construction sectors. The exploratory socio-economic impact study carried out by LNEG demonstrated that STE could contribute to creating an estimated number of direct and indirect jobs of 3,840, in 2030 only.

5.4.3 Integrated findings

5.4.3.1 Excellent institutional positioning between R&I academia and industry policy

- As in all member states, the Portuguese energy strategy follows primarily the government's priorities and – more specific to Portugal - benefits from the excellent institutional positioning of LNEG and DGEG between R&I entities and the guiding institutions for industry policy.
- Although solar research in Portugal is well established (by several recognised research entities as described under section 5.3.1.2), the promotion via various national events and general communication in favour of a larger deployment of the CSP technology appears improvable.
- Research activities related to the development of CSP projects funded by the national funding agency, respectively supported at present by the national state budget and by the Portugal 2020 programme, appear as a stable framework for CSP, but the announced thinning of funding after 2020 is perceived as a matter of concern, in case unchanged funds would have to be divided between different research and industrial entities, with tight deadlines for each project.

5.4.3.2 Improvements towards a "true" Iberian approach regarding the auction design, storage challenge and RES procurement policies

- Currently there is no cooperation between Portugal and Spain when it comes to the design of their respective procurement mechanisms for new RES capacities. This means that the specific conditions of such auctions are strikingly different between Spain and Portugal despite the fact that the Portuguese and Spanish day-ahead markets grew together after 2014 into an integrated market (the Iberian Electricity Market - MIBEL) with a joint electricity exchange. A main point of concern is the fact that in Portugal, the RES auctions include the connection point whereas in Spain the connection point to the HV grid is auctioned separately. This may lead to excessively low levelised cost of electricity as auction results possibly offset by trading beyond the sale of the new added capacity.
- In upcoming years, the technical solutions for building new storage capacities will diversify all over Europe and ongoing research as well as further projects in Portugal should demonstrate the reliability of the use of TES in this context so to match high expectations for the development of new hydrogen market in Portugal.

5.4.3.3 Deeper socio-economic impact on Portugal's economically stressed regions

- Portugal has fostered the development of new business opportunities for national companies since Portugal sees a potential in several national companies with strong capabilities in various areas of relevance for the CSP field. The LNEG's exploratory assessment has confirmed this potential to deploy CSP in Portugal and its socio-economic benefits for the country.
- Simultaneously, Portugal strives to attract foreign direct investments.
- The contribution of CSP to achieve the energy strategy goals of Portugal is linked to the development and/or implementation of new clusters, concepts or projects. Even though there are no Portuguese companies directly involved yet in such endeavours, this suggests that new business opportunities in CSP sector exist for local companies.
- Deploying CSP in Portugal would benefit especially to 2 regions, Alentejo and Algarve. These are rural areas with fewer productive activities beyond tourism where the construction of CSP facilities in those regions would create local employment during construction time and over the lifetime of the plant.
- The impact study on the socio-economic benefits carried out by LNEG is based on comparative analysis of Spanish statistical data since the labour and economic structures are similar between the two countries and a substantial amount of Portuguese workforce was involved during the construction of CSP plants in Spain. Without any new CSP plant constructed in Europe over the last decade, assuming that manufacturing and construction techniques would differ today – which makes comparisons difficult -, a large CSP plant could represent around 12 FTE jobs per year per MW for construction and 0.9 FTE per year per MW for O&M services.

5.4.3.4 Business opportunities for Portuguese and Spanish industry in extended uses of CSP

- Our research shows that the industry players in the Iberian Peninsula do not coordinate bilateral concepts resulting in lack of mutual benefits for both countries. A better cooperation or even joint ventures of Spanish and Portuguese companies fed by common research activities in CSP technology would be able to deter the technology development notably towards generation of process heat and new fuels / hydrogen, considered on both sides of the border as one of the energy strategy priorities.
- In this context, Spain and Portugal have under the recast RES Directive 2018 the full access to the Cooperation Mechanisms proposed by the European legislation.

5.4.3.5 Limited interconnection capacity is not a barrier for CSP deployment

- A reinforcement of the transfer capacity between Portugal and Spain is considered in the upcoming decade, starting with a new high voltage line which should be operational in 2022 in the North of Portugal.

- It seems that the continued Portuguese government's push for the development of interconnections, as emphasised in the NECP, implicitly calls for a closer Portuguese – Spanish alliance. Developing such necessary grid infrastructure to strengthen market integration is pivotal to create the necessary technical and operational conditions as well as a good basis to increase cooperation in the R&I activities dedicated to new blended uses of renewable technologies such as CSP.

5.5 Aligned conclusions and recommendations

- Strengthen the support for aligning research and industry policy to overcome the thinning funding beyond 2020 via already ongoing EU funding programmes and additional investments and cooperation projects with other Member States.
- Align the RES procurement auction features between Spain and Portugal, and also regarding the optimisation of the solution to the storage challenge across the Iberian Peninsula.
- Consider the potential job creation and the related socio economic benefits (services, local businesses, etc.) of CSP development in Portugal based on the experience gained in Extremadura during the construction of CSP plants in Spain.
- Proactively support industrial cooperation between Portugal and Spain on extended uses of CSP, such as industrial process heat or new fuels which could lead to know-how transfers both at industrial and R&I level.
- Take a common *political* initiative by authorities in Portugal and Spain (assimilable to a positive response to the possibility of using the Cooperation Mechanisms (see section 5.4.3.4), either at national or regional level towards cooperation would stimulate a wider Iberian cooperation in the RES sector taking advantage of the best natural conditions in Europe.
- Maintain a stable funding framework for R&I on extended CSP applications beyond 2020 in line with the NECP targets.

5.6 Glossary

APREN	Portuguese Association of Renewable Energy
CSP	Concentrated Solar Power
CST	Concentrated Solar Technologies
DGEG	Directorate General for Energy and Geology
DSO	Distribution System Operator
EC	European Commission
EDP	Energías de Portugal
EMSP	Évora Molten Salt Platform
ERSE	Energy Services Regulatory Authority
EU	European Union
FAI	Innovation Support Fund
FCT	Foundation for Science and Technology
GWh	Gigawatt hour
H2020	Horizon 2020
INIESC	National Infrastructure on Solar Energy Concentration
kWh	Kilowatt hour
LNEG	National Laboratory of Energy and Geology
MS	Member States (EU)
MVA	Megavolt Ampere
MW	Megawatt
NECP	National Energy and Climate Plan
O&M	Operation and Maintenance
OP	Operational Programme
PECS	Solar Concentrators Testing Platform
PV	Photovoltaic
R&D	Research and Development
R&I	Research and Innovation
RCN2050	Roadmap for Carbon Neutrality 2050
REN	Redes Energéticas Nacionais
RES	Renewable Energy Sources
SET Plan	Strategic Energy Technology Plan
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TSO	Transmission System Operator
UÉvora	University of Évora

5.7 Appendices

5.7.1 References

Portugal – R&I

EU-SOLARIS, European Solar Thermal Research Infrastructure for Concentrated Solar Power website [online]

INIESC - National Research Infrastructure in Solar Energy Concentration website [online]

Portuguese Directorate-General for Energy and Geology website [online]

Portuguese Roadmap of Research Infrastructures, 2020 [online]

Programme CSP ERANET website [online]

Programme Portugal 2020 website [online]

Programme Portugal 2030 website [online]

The Innovation Support Fund website [online]

Portugal – Industry

Energy Services Regulatory Authority, ERSE's 2019-2022 Strategic Plan, September 2019 [online]

Ministry of Environment and Energy Transition, Roadmap for Carbon Neutrality 2050 (RNC2050), June 2019 [online]

Portuguese NECP [online]

REN, Technical Data 2019, 2019 [online]

5.7.2 Meeting guidelines

See APPENDIX.

5.7.3 Interview guidelines

See APPENDIX.

6 Chapter 6: France

6.1 Structure of the document

The "Integrated Country Report – France" aims to provide a global and structured approach of the country's profile regarding potential interest to STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2. Since no partner from France is part of the consortium, information for the R&I part were drawn from the different interviews ESTELA had in the frame of WP2 activities, as well as from Deliverable D.1.2, Report on Current Framework Conditions to which R&I partners contributed. The aim is to reflect:

- The expressed need for manageable RES energy by the country of focus and the strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.
- The construction of a defined framework for funding and its reception by relevant audiences.
- The evaluation of performance of the funding frameworks.

Section 6.2 summarises the tasks which were carried out, both on R&I (6.2.1) on the industrial (6.2.2) side. This gives an overview of the intelligence collected and of the final key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Proposition of a reshaped funding framework based on feedback from stakeholders and the Implementation Working Group.
- Dissemination of information about the funding opportunities and impact evaluation.
- Meeting with relevant stakeholders, i.e. at Ministry, Transmission System Operator (TSO) and Regulatory Authority levels, as well as key players from local industries and civil society.
- Brokerage events and joint industry-R&I national events.

A deeper analysis of the context of each country is provided in section 6.3, first for the research section (6.3.1) and then for the industry (6.3.2). Each of these sections provides a global overview of the different factors influencing the development of funding and commercialisation of STE applications. More precisely, it aims to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in France.

Based on these observations, integrated key findings are drawn in section 6.4. They highlight encountered challenges and existing opportunities and draw a picture of the potential synergies between R&I and industry structures.

Last but not least, section 6.5 suggests strategic actions to continue opening doors for STE in France, in an overarching approach to further support the development of STE, combining R&I and industry perspectives to offer thorough advice.

6.2 Summary of undertaken activities

France has been under the scope of analysis from April 2020 until June 2022. The Covid-19 pandemic has slowed down the working process. Notably, ESTELA has collaborated with ENEA regarding the information related to R&I. Furthermore, as the consortium does not include any French partner, ESTELA received a strong support from RTE, CNRS, CEA, ENGIE and TotalEnergies to maximise impacts and meaningful results.

The following chapters will describe the work undertaken in France and analyse the challenges and opportunities met in the country.

6.2.1 R&I methodology

To have a wide overview of the R&I landscape of France the following activities were carried out:

List of activities	Timeline
Documentation phase	Oct. 2021 - June 2022
Aim: To collect the information available about R&I in France related to CST technologies (stakeholders, research centres, funding sources,)	
Description: Since there is no French partner in the HORIZON-STE project, ENEA carried out own desk research to collect all the information available about R&I in the CST sector. Taking also into consideration the synergies between this Integrated Country Report and the content of the National Concept Note of France to be elaborated within the framework of WP3 in the European SFERA-III project, people responsible for that Concept Note were contacted by ENEA to get further information about relevant R&I activities in France. People from CEA and CNRS were also contacted to get several documents with information about industries, research centres, research facilities and funding sources in France for R&I activities related to CST technologies and applications.	
Processing of information and writing of report	Dec. 2021 – June 2022
Aim: To write the sections devoted to R&I in this Integrated Country Report of France	
Description: All the information collected during the documentation phase was analysed and processed by ENEA in order to get the R&I landscape of France for CST technologies and applications, especially those directly related to the SET Plan for CSP. It was also included in this analysis the information collected by ENEA from French entities when preparing the Deliverable D1.4 ("Report on options for financing instruments and schemes") of HORIZON-STE project. The result from this analysis is given in section 6.3.1 of this document (Overview of the context in France: R&I Landscape"). Key findings from this information analysis and processing are given in section 6.4.1.	

6.2.2 *Industry*

6.2.2.1 Foreseen activities and implementation challenges

To favour a sustainable launch of STE in studied countries, ESTELA designed a general process unfolding in three steps with flexibility to adapt to specific country challenges:

PHASE 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and France's strategies on its procurement / possible changes in the relevant framework conditions
Encountered challenges	To find the right interlocutor Low answer rate to interview requests Mixed information received from different interlocutors
Applied mitigation	- Research to identify relevant stakeholders; - General translation of official documents from French to English - Confrontation of different sources with the official source
PHASE 2	
BROKERAGE EVENT	
General aim	Assessment and presentation of potential solutions using CSP/STE
Encountered challenges	- Outbreak of covid-19 global pandemic - Little renewable solar in the energy mix and strong place of nuclear
Applied mitigation	- On-line meetings with national stakeholders
PHASE 3	
JOINT NATIONAL EVENT	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	- Outbreak of covid-19 global pandemic - Not enough data collected yet
Applied mitigation	- Awaiting the end of the pandemic to evaluate the possibilities

6.2.2.2 Carried out activities

LIST OF ACTIVITIES	TIMELINE
BACKGROUND RESEARCH	Phase 1 Sep. 2021-Apr. 2022

Aim: To collect relevant information to better understand the energy landscape in France, the potential challenges for the development of STE and the needs of the country

Description

Desk research: Collect of information based on available information on official websites (e.g.: RTE, CEA, ENGIE, CNRS, TotalEnergies, Ministre de la Transition écologique, European Commission, Enerplan ...), academic studies or reports by consultancies

LIST OF ACTIVITIES	TIMELINE
Stakeholder mapping: Analysis of the specific relevant departments and actors for each identified target group Exchanges with CEA and RTE on relevant contacts and existing knowledge of the local situation Exchanges with ENGIE, EDF and TotalEnergies on existing challenges and potential creation of an STE business case to be presented to the Ministry	
PRELIMINARY TALKS	Phase 1 Oct.-Dec. 2021
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable RES, the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions	
Description Ideally, this phase aims to establish a first physical contact with the three key stakeholders in France regarding energy policy, namely TSO, the Ministry and the Regulatory Authority. However, as the Covid-19 pandemic forced EU borders to be closed and travels to be restricted, HORIZON-STE could not organise these meetings and had to hold them online: **RTE** Interview with a stakeholder involved in Market Models and Economic Studies **DGEC** No reply to the invitation for a meeting with the Directorate General for Energy and Climate (DGEC) of the Ministry of Ecological Transition **Vallourec** Interview with a stakeholder from the company **Corning** Interview with a stakeholder from the company **Tecsol** Interview with a stakeholder from the company **CEA** Interview with three stakeholders respectively involved in EU projects related to CSP, solar & thermodynamic studies and EU roadmaps **CNRS** Interview with two stakeholders from CNRS-PROMES **ENGIE** Interview with a stakeholder from the company **TotalEnergies** Interview with two stakeholders involved in Solar Thermal Business Development	
INTERVIEWS	Phase 1 Oct.-Dec. 2021
Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of France's energy strategy and potential need for manageable RES	
Description **Industry:** Interview to gather insights into renewable portfolio, conditions for a technology to be interesting, current role in the energy transition in France.	
BROKERAGE EVENT	Phase 2 Oct.-Dec. 2021
Aim: To have a broad overview of STE perspectives in France through existing and potential solutions using STE, from both the R&I and industry sides.	
Description A series of online meetings with national stakeholders were held as a mitigation measure due to the COVID-19 pandemic restrictions.	

LIST OF ACTIVITIES	TIMELINE
NATIONAL EVENT	Phase 3 July 2022

Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the development of STE in France. To focus on possible synergies and macro-economic value.

Description

The joint industry and R&I national event took place on 12 July 2022 online via Webex. The main conclusions and highlights of the event will be reported in the Deliverable 4.7 "Proceedings of the Joint Industry and R&I Events".

6.3 Overview of the context in France

6.3.1 R&I landscape

This section presents the main outcome of the background research and the analysis of the information and opinions collected from ENEA's own desk research and inputs from CNRS and CEA. It is divided into the financial framework, the ongoing activities of French R&I entities and the cooperation at national and international level that have an impact into the focus of research and funding.

The law on the energy transition for green growth (LTECV) provides for (Article 183, II) the development of a national energy research strategy (Stratégie nationale de recherche énergétique, SNRE)[118], drawn up by the ministers for energy and research. This strategy, which specifies the energy component of the national research strategy (SNR), aims to identify the research and development (R&D) challenges and scientific obstacles to be overcome over different timeframes and throughout the innovation chain in the field of energy to ensure that the objectives of the law are met, while taking a broader international perspective. Furthermore, the SNRE must consider the national low-carbon strategy (Stratégie Nationale Bas-Carbone, SNBC) and the multi-annual energy programme (programmation pluriannuelle de l'énergie, PPE).

The development of this strategy, carried out jointly in 2016 by the Directorate-General for Energy and Climate (Ministry of Ecological Transition) and the Directorate-General for Research and Innovation (Ministry of Higher Education, Research and Innovation), was based on a monitoring committee bringing together all the stakeholders in energy research. It includes representatives of public R&D bodies, alliances and, more generally, the scientific world, representatives of companies active in energy R&D and innovation, and representatives of the member organisations of the National Council for Ecological Transition - CNTE - (professional federations, trade unions, NGOs and environmental protection associations, local authorities, elected representatives) and the administrations concerned.

The SNRE was validated by a joint order of the ministers in charge of energy and research, published in the JO on 27 December 2016.

After the SNBC and the PPE adoption, in November 2015 and October 2016 respectively, the SNRE became the new strategic tool for French research and innovation players to enable the emergence of the energy system of tomorrow.

The SNRE is organised according to four main guidelines, each of them includes proposals for structuring actions. The strategy aims to provide resources to innovation actors, help them develop new knowledge and bring new products from lab to market, and foster socio-political support by promoting transparent governance and collaborative projects.

Specifically, the SNRE sets four main objectives to shape the future of France's R&D:

- Focus on the transition of the energy system by stimulating multidisciplinary R&D, involving environmental science, digitalisation, and economic and social science,

[118] *https://www.ecologie.gouv.fr/sites/default/files/SNRE%20vf%20déc%202016.pdf*

consumer involvement and decentralisation, as well as the analysis of several options of flexibility of energy supply and demand management.

- Develop R&D in tandem with regions and industry, in particular small and medium sized enterprises (SMEs), to promptly transfer technologies from R&D laboratories to the market.
- Develop the necessary skills and knowledge by strengthening international collaboration, the creation of global networks of researchers, expansion of modelling and forecasting capacities, the deployment of training courses for jobs associated with the energy transition, and the involvement of civil society.
- Create a high-performing governance through the monitoring committee, which is convened every year to review the SNRE with ministries responsible for research, innovation and energy; the National Research Agency (Agence nationale de la recherche - ANR)[119]; the Agency for Ecological Transition (Agence de la transition écologique - ADEME)[120]; and the National Alliance for the Coordination of Energy Research (Alliance Nationale de Coordination de la Recherche pour l'Energie - ANCRE)[121].

Furthermore, this governance guideline highlights the need to coordinate the implementation of the SNRE with existing initiatives at different geographical levels, from local (in particular at regional level) to the international level (in particular at European level with the European Union Research & Innovation Framework Programme and the SET Plan).

To this end, it is proposed to:

- Convene the Stakeholder Committee on an annual basis after the adoption of the of the SNRE, to drive and monitor its implementation and prepare its future revision, according to a 5-year cycle, coordinated with those of the SNBC, the PPE and the SNR;
- Provide for an ex-post evaluation of the SNRE by the Parliamentary Office for the Evaluation of Scientific and Technological Choices (Office parlementaire d'évaluation des choix scientifiques et technologiques, OPECST);
- Set up a regular exchange with the regions on R&D priorities, support actions, and funding;
- Monitor France's compliance with its commitment to double clean energy R&D funding as part of the Mission Innovation initiative;
- Ensure that French and international R&D funding mechanisms are complementary. For example, at the European level, France could promote the reinforcement of the Horizon 2020 programme on low Technology readiness level (TRL) research and ensure that the innovation support fund provides financing for low-carbon large-scale projects.

[119] *https://anr.fr*

[120] *https://www.ademe.fr*

[121] *https://www.allianceenergie.fr*

Energy R&I is a joint effort of the Ministry of the Ecological Transition and the Ministry of Higher Education, Research and Innovation. The SNRE is the fruit of their strong collaboration. To support the co-ordination and implementation of the SNRE across the government, a permanent secretariat and a monitoring committee are in place. The ANCRE and ADEME participate in the work of the committees, but industry and academia do not directly.

A diverse set of entities are involved in France's energy research and innovation ecosystem. For the most part, decision making for innovation priorities is centrally led by the government, with a consultative role and some responsibilities in implementation for regions and local authorities, such as to set up technology innovation clusters.

France has a very low-carbon electricity mix owing to its large nuclear fleet. As an early leader in setting out an ambitious energy transition, France legislated a net zero emissions target for 2050 in its 2019 Energy and Climate Act. A national low-carbon strategy with 5-year carbon budgets and a multiannual plan for energy investments complement the long-term target.

France plans to reduce the share of nuclear from 70% to 50% in its electricity mix by 2035 and close its last coal plants by 2022. Many nuclear reactors are reaching the end of their lifetime, which requires modernising those that can continue long-term operations under safe conditions. Maintaining security of the electricity system and a low-carbon footprint while reducing the share of nuclear energy will require investments in efficiency, renewable energy and enhanced and flexible power system operation.

France is committed to a major process of ensuring the long-term transformation of the economy, which must be more circular, carbon-free and sustainable. Research and innovation are essential components of this process and are necessary for the development of solutions that are virtuous, competitive and socially acceptable. Thus, research and innovation will remain the cornerstones of national policies on energy transition in the coming years to achieve the targets set for 2030.

With the ambitious targets set in the 2020 SNBC and the PPE, the 2016 SNRE needs to be updated. The authors see several key opportunities for France to focus on clean energy innovation in the context of the preparation of the SNBC for 2024 and setting future funding programmes, in light of the sustainable recovery of the French economy following the COVID-19 pandemic and future investment under the Investment 2030 Plan.

France's energy research community is present across the entire R&D value chain, and public sector actors are typically involved at least to some extent in all steps of technology development, from basic and applied research to demonstration.

- Fundamental research is primarily performed by public laboratories under the National Centre for Scientific Research (CNRS), including in research facilities located in institutions of higher education such as universities, scientific and engineering schools, and *"grandes écoles"*, France's elite academic institutions.
- Applied research and demonstration are carried out by public bodies, including the Alternative Energies and Atomic Energy Commission (CEA), and by the industry.

- Pre-commercial experimentation, product development and demonstration in some instances are conducted by industrial companies, in partnership with public laboratories and public industrial and commercial establishments.

6.3.1.1 Funding opportunities for R&I activities in France related to CST technologies

Funding opportunities for Concentrated Solar Technologies (CST) research, development and innovation exist at regional, national, European and international levels.

The policies, general objectives and the budget for research in France are defined by the Ministries and the Strategic Research Council under the Prime Minister. Thematic priorities and budget allocation are programmed by the ministries and the funding agencies. These include mainly the ANR under the lead of the Ministry of Higher Education, Research and Innovation and ADEME under the Ministry of the Ecological Transition, as well as BpiFrance, France's public investment bank.

In addition to funding public institutions, the French government actively supports collaborative research projects between public and private R&D actors, as well as innovative projects by companies throughout the innovation chain via the Investments for the Future Programmes (Programme d'investissements d'avenir, PIA).

ANR supports upstream projects (low TRL).

The action relating to the Institutes for Energy Transition (ITE), operated by the ANR, aims to set up reference technological innovation campuses in new energy technologies, bringing together companies and laboratories, with a triple ambition of defining and conducting research programmes, developing the results of this research economically, and participating in the effort to train professionals for the energy transition.

These public-private research centres (ITE) constitute a structuring base for research and innovation activities in the following fields:

- Green chemistry and agro-based materials: PIVERT.
- Solar energy: IPVF and INES2.
- Electrical networks: SUPERGRID.
- Energy efficiency and sustainable cities: EFFICACITY.
- Sustainable buildings: INEF4.
- Decarbonised and connected vehicles: VEDECOM.
- Renewable marine energies: France énergies marines.
- Geothermal energy and underground technologies: Géodénergies.

In parallel to the PIA, the ANR also operates a programme for funding fundamental research based on annual calls for projects targeted at the priorities defined by the national research strategy, which has in particular identified a challenge entitled "clean, safe and efficient energy", with 5 axes:

- Dynamic management of energy systems.
- Multi-scale governance of energy systems.

- Energy efficiency in all sectors of the economy.
- Reducing the need for strategic materials
- Decarbonisation of energy and chemistry.

ADEME supports demonstration projects and is active in the implementation of public policy and provides expertise and advisory services to businesses, local authorities and communities, government bodies, and the public at large. As part of this work, the agency helps finance projects, from research to implementation, in its areas of action, such as PIA. Namely, ADEME acts as an operator of the PIA on strategic themes and aims to support, in particular through State aid (subsidies and repayable advances), research and innovation demonstrators in the following areas:

- Renewable energies.
- Decarbonisation of energy use, energy efficiency.
- Energy storage, conversion and smart grids
- Sustainable building and in particular energy renovation.
- Water and biodiversity.
- The circular economy.
- New mobility solutions, technologies and transport infrastructures that are less fossil-fuel intensive and have less impact on the environment.

BpiFrance, France's public investment bank, supports innovative companies, mainly support micro-businesses, SMEs and mid-caps but also accompany large caps that are considered important to the interests of France in terms of national economy, the territories or employment.

BpiFrance offers a continuum of solutions adapted to every key step in a business' growth such as: business creation, financing, guarantees or equity investment. BpiFrance also operates the Single Inter-Ministerial Fund (FUI) on behalf of the State, supporting, in conjunction with the regions, collaborative projects identified by the competitiveness clusters.

The funding agencies work with several alliances and research organisations. For the energy sector, the National Alliance for the Coordination of Energy Research is the key alliance of research organisations and participates in the implementation of the national strategy and is active in the European Energy Research Alliance (EERA).

Over the past decade, public research, development and demonstration (RD&D) funding has remained relatively flat, around EUR 1.2 billion (bln) in public funding for energy RD&D, corresponding to roughly 9% of French public spending for R&D and 0.05% of national gross domestic product (GDP). Energy R&D spending is, to a large extent, dedicated to nuclear energy (mainly fission), energy efficiency and cross-cutting research areas. The flat funding levels also mean that France was not able to deliver on its Mission Innovation pledge, which required doubling the clean energy innovation spending by 2020 compared to 2015.

While public institutions carry out much of France's R&D activities in the early stages of technology development, companies typically allocate the bulk of innovation budgets on demonstrating new concepts and developing new and improving existing products. To complement investments in traditional RD&D, France mobilises funding to support business innovation and foster the creation of markets for emerging energy products and services.

In 2010, the government launched the PIA implemented by ADEME, Bpifrance and the Caisse des Dépôts. The programme includes equity investments, calls for demonstration funding, SME interventions and collaborative industrial projects. It seeks to support public and private actors – from idea to markets along the entire innovation value chain – to develop new concepts and technologies in strategic areas that can contribute to medium-term structural economic growth and job creation in France. Four PIA tranches of funding and support mechanisms were set up successively in 2010, 2014, 2017 and 2020. Supported by the French Recovery Plan, the PIA-4 (2021-25) will mobilise an additional EUR 11 bln for innovation, bringing total PIA-4 budgets to EUR 20 bln.

Specifically for CST projects, both ANR and ADEME can fund R&I projects at the national level. In general, ANR supports lower technology readiness level projects than ADEME. For example, ANR has funded CST related collaborative R&I projects on components such as advanced modelling of fluid flow in solar receivers, selective coatings, high temperature materials for CST and thermal energy storage (TES). The level of funding from ANR is generally less than €500.000. ADEME funds large project (some € Million) but with a different funding scheme and is associated with subsidies and repayable advances.

On the regional level, each of the thirteen French regions can elaborate a research and high education plan with associated Call for proposals and funding schemes. For example, Occitanie region aims at being a "Positive Energy Region" by 2050 and established a roadmap that defines the various renewable energy options to be supported by R&I regional funds. Proposed energy production options are methane from biomass, solar PV, offshore wind and hydrogen. In this latter domain, the region has funded a CNRS project on solar thermochemical hydrogen production. Moreover, the Region supports the solar technology platform of Themis that includes the 5 MW power tower operated by CNRS-PROMES.

Most of the fund for CST related activities in France came from collaborative research and innovation projects funded through the European Union Research and Innovation Framework Programmes. In this context CNRS and CEA have coordinated and participated in many European projects. Table 30 lists some of the most recent CST projects (started after January 2017). Further opportunities will come from the HORIZON Europe Programme, mainly through the Cluster 5 "Climate, Energy and Mobility" Calls.

The participation of CNRS in research projects funded by the European Union reveals a particular predilection for research activities dedicated to the development of the next generation of concentrating solar power plants. In particular, to the development of new central receivers or innovative heat transfer fluids to achieve extremely high thermal conversion efficiencies compared to the state of the art. In fact, CNRS was the coordinator of the CSP2 (Concentrated Solar Power in Particles) and Next-CSP (High Temparature concentrated solar thermal power plan with particle receiver and direct thermal storage) projects. Furthermore, CNRS participated to the G3P3 project, "Gen 3 Particle Pilot Plant (G3P3): Integrated High-Temperature Particle System for CSP" managed by Sandia National Laboratory, Albuquerque, and funded by US-DOE in 2019-2021.

While CEA involvement in European funded projects is more in line with national mission, mainly works in strong collaboration with industrial actors. Indeed, CEA coordinated the WASCOP action, which aimed to provide innovative solutions to reduce the water consumption in commercial CSP plant. Furthermore, CEA is the key French institution for promoting the use of industrial heat produced by concentrated solar thermal technologies. With this regards it is worth to mention their role in INSHIP, SHIP2FAIR, and FRIENDSHIP project.

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	French Industrial Partners	French R&I Partners
EU	Advanced Materials technologies to QUADRUPLE the Concentrated Solar Thermal current POWER GENERATION	IN-POWER	LEITET	2017-2021	---	CEA
EU	Solar Facilities for the European Research Area - Third Phase	SFERA-III	CIEMAT	2019-2022	EURONOVIA	CNRS; CEA
EU	Supercritical CARbon dioxide/Alternative fluids Blends for Efficiency Upgrade of Solar power plants	SCARABEUS	Politecnico di Milano	2019-2023	KELVION THERMAL SOLUTIONS	---
EU	DEmonstration of CSP coupled wIth advaNced desAlinaTion system in the gulf regION	DESOLINATION	Politecnico di Milano	2021–2025	EUROQUALITY SARL;	

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	French Industrial Partners	French R&I Partners
EU	Small-Scale Solar Thermal Combined Cycle	POLYPHEM	CNRS	2018–2022	EURONOVIA	CNRS; CEA;
EU	Solving Water Issues for CSP Plants	SOLWARIS	TSK	2018–2022	BERTIN TECHNOLOGIES SAS	CEA
EU	Thermochemical HYDROgen production in a SOLar structured reactor: facing the challenges and beyond	HYDROSOL-beyond	CERTH	2019–2023		CEA
EU	POwering SYstem flexibiliTY in the Future through RES	POSYTYF	ECOLE CENTRALE DE NANTES	2020–2023	RTE; ENEDIS; DOWEL INNOVATION	ECOLE CENTRALE DE NANTES
EU	Integrating National Research Agendas on Solar Heat for Industrial Processes	INSHIP	Fraunhofer – ISE	2017–2020		CEA, CNRS

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	French Industrial Partners	French R&I Partners
EU	Solar Heat for Industrial Process towards Food and Agro Industries Commitment in renewables	SHIP2FAIR	CIRCE	2018–2023	EDF; SNC JEAN LARNAUDIE	CEA;
EU	Forthcoming Research and Industry for European and National Development of SHIP	FRIENDSHIP	CEA	2020–2024		CEA; INES
N (ANR)	Multilayer Multifunctional Advanced Coatings	2MAC-CSP	CNRS	2018-2021		CNRS
N (ANR)	Optimization of TES thermocline	OPTICLINE	CNRS	2017-2020		CNRS

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	French Industrial Partners	French R&I Partners
N (AAP INFRA REGION)	Maitrise du flux solaire concentré et de la température au foyer de la centrale à tour Thémis et du four solaire d'Odeillo	Clé-de-Sol	CNRS	2020-2022		CNRS
N (ANR)	Nanocomposites en couches minces élaborés par Plasma pour applications Solaires Thermodynamiques sous concentration	NANOPLAST	CNRS	2019-2021		CNRS

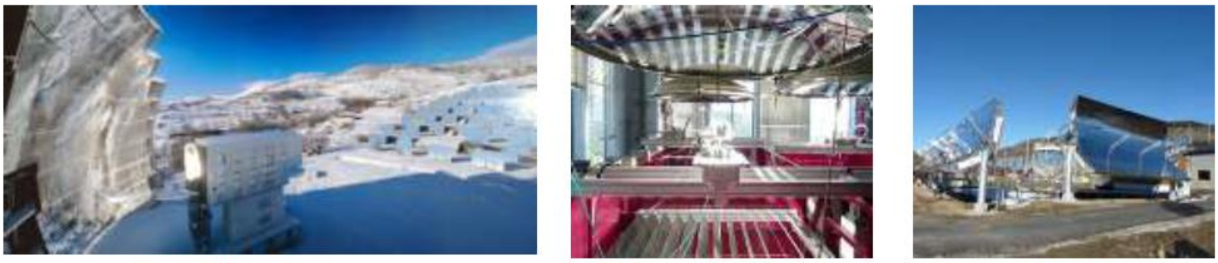
Table 30: R&D Projects with involvement of France relevant to the SET IP (only those projects starting in 2017 or later have been included)

6.3.1.2 Existing R&I activities

France institutions have a well-established background in CST research, both at national and international level. France's energy research community is present across the entire CST R&D value chain, and public sector actors are typically involved at least to some extent in all steps of technology development, from basic and applied research to demonstration. The main R&I stakeholders in France are CNRS and CEA. The main national research infrastructure on CST technologies is located in Font Romeu and Cadatrache.

The PROMES laboratory (Figure 37) is a CNRS Proprietary Unit (UPR 8521) attached to the Institute of Engineering and Systems Sciences (INSIS) under agreement with the University of Perpignan via Domitia (UPVD). The laboratory is located on three sites: Odeillo-Font Romeu (CNRS 1 MW solar furnace), Targasonne (Thémis, 5 MW tower power plant, site of the Conseil Départemental des PO) and Perpignan, Tecnosud. The laboratory brings together about 150 people from the CNRS and the UPVD around a unifying subject, solar energy and its valorisation as a source of energy and high temperatures. PROMES leads the laboratory of excellence SOLSTICE (SOLAR: Sciences, Technologies, Innovations for Energy Conversion)[122].

One of the missions of PROMES is to develop research with the large French concentrating solar power plants of the CNRS in Font Romeu (solar furnaces in particular) and of the Conseil Général des Pyrénées Orientales in Targasonne (Themis solar tower). This research can be carried out up to the research demonstrator stage. In addition, the laboratory is in charge of the development of the national research platform on concentrated solar power, which was made possible by the Equipex SOCRATE (SOlaire Concentré: Recherches Avancées et Technologies Energétiques) and is very active in the management of the DERBI competitiveness cluster.



The 1 MW solar furnace | **The small-scale solar furnaces** | **The parabolic troughs miniplant**

Figure 37: CNRS-PROMES CST infrastructure

The University of Perpignan's energy-focused training programmes are supported by PROMES, in particular the SupEnR engineering school, the Energy and EEA Masters and the EUREC European Masters (Speciality: "Solar thermal").

PROMES has opened its exceptional facilities to the European research community through the SFERA-III and EU-SOLARIS projects. Very involved in European research,

[122] https://www.promes.cnrs.fr/

PROMES coordinates the Next-CSP and POLYPHEM projects dedicated to the development of new solar power plant concepts.

To achieve the objectives of carbon neutrality by 2050, the CEA is working on many building blocks of the low-carbon energy production system: support for current and future nuclear power plants, including the development of small modular reactors, R&D on solar energy and hydrogen.

CEA Tech is the "technological research" department of the CEA, historically located in the Auvergne-Rhône-Alpes and Ile de France regions. CEA Tech is made up of the three institutes Leti, Liten, and List and the regional CEA Tech institute, which provide it with a complete portfolio of technologies in the fields of information and communication, energy, and health.

As a major technological research centre, the CEA-Liten plays a decisive role in the development of future technologies for the energy transition and the limitation of greenhouse gas emissions. Regarding these challenges, Liten and its ecosystem innovate with the objective of creating value and transferring it to industry and the economic world.

The CEA-Liten[123] centre in Cadarache is involved in research on hydrogen, the production of synthetic fuels and solar energy. The Cadarache platform's tests in real sunlight provide technological support to the National Solar Energy Institute (INES)[124], which has been based in Chambéry since 2005. INES is the French reference centre in the field of solar energy: photovoltaic solar energy, solar thermal energy, combined systems, solar air-conditioning, integration in buildings and solar mobility.

(a)

(b)

Figure 38: Figure 2: CEA CST infrastructure: (a) ALSOLEN demonstrator, and (b) SOLARBOX demonstrator

The CNRS and CEA are currently the most active entities in terms of involvement in projects on concentrated solar thermal technologies. CNRS operates the French research infrastructure on CST, FR-Solaris, which is the National Node of the European Research Infrastructure EU-Solaris, while CEA operates three demonstrators, based on linear system technologies, in Cadarache (Figure 38).

[123] *https://liten.cea.fr/cea-tech/liten/english/Pages/CEA-Liten/About-us.aspx*

[124] *https://www.ines-solaire.org/en/*

Table 31 below summarises some of the most relevant research infrastructure currently available in France.

Name	Location	Owner	Description
1 MW solar furnace	Font Romeu-Odeillo	CNRS/ PROMES	1 MW large-scale solar furnace
Small-scale solar furnaces	Font Romeu-Odeillo	CNRS/ PROMES	12 solar furnaces, SF (10 small-scale -1 & 1.5 kW DF-, one 6 kW)
Themis solar tower	Font Romeu-Odeillo	CNRS/ PROMES	5 MW_{th} research demonstrator on particle receiver CSP
Mini PT+TES	Font Romeu-Odeillo	CNRS/ PROMES	50 kW_{th} parabolic trough miniplant including a 220 kWh thermocline thermal energy storage using oil as heat transfer fluid
ALSOLEN	Cadarache Research Centre	CEA/L2TS	ALSOLEN demonstrator is a 1000 m^2 linear Fresnel solar unit and was built in 2012. It produces electricity, drinkable water and cooling. The heat transfer fluid is a synthetic oil that is heated up to 300°C and a thermocline storage system is included to the unit.
ALSOLENSUP	Cadarache Research Centre	CEA/L2TS	ALSOLENSUP demonstrator is a 1600 m^2 linear Fresnel solar unit and was built in 2015. It produces water steam at 450°C under a pressure of 110 bar.
MICROSOL	Cadarache Research Centre	CEA/L2TS	MICROSOL is a 300 kW_{th} parabolic trough demonstrator located in Cadarache CEA's center, built in 2015 and coordinated by Schneider Electric. The heat fluid transfer is water that is heated up to 180 °C and is directly stored in a tank. Electricity is produced with an organic Rankine cycle.
Heat distribution network	CEA/INES Research Centre	CEA/L2TS	A micro heat distribution network has been built in 2018. The heat is produced either by a 280 kW gas boiler or a 300 m^2 flat thermal solar panels unit. A power-to-heat unit is planned to be installed. Advanced monitoring algorithms are being tested with heat load emulation.
SOLARBOX	CEA/INES Research Centre	CEA/L2TS	4 kWth solar panel for medium temperature production. The collector has been connected to the heat distribution network for its demonstration in a relevant environment. The SOLARBOX has now entered an industrialization phase.

Name	Location	Owner	Description
VALTHERA	School of Mining Engineers Albi-Carmaux	School of Mining Engineers Albi-Carmaux	The School of Mining Engineers Albi-Carmaux, one of France's top engineering institutes, and the CNRS RAPSODEE Research Centre in Albi are operating since January 2017 VALTHERA, a technological platform dedicated to the development of energy-efficient thermal processes for the recovery of biomass processing residues and by-products that combine biomass and solar thermal. To do this, the Center has developed a Beam-Down Solar Thermal Concentrator concept with heliostats (this project included the French oil&gas group TotalEnergies). 16 m^2 mirrors are now being installed on the roof of the building in order to provide clean energy (10 kW_{th})

Table 31: CSP/T research infrastructure in France

6.3.1.3 National and international cooperation

France strongly supports the R&I cooperation. At the international level, France is active in 22 IEA Technology Collaboration Programmes, Mission Innovation (MI), and EU Energy Technology Initiatives. France has actively participated in all the actions of the EU Strategic Energy Technology Plan. CEA is one of the founders of the EERA. CEA and CNRS are active in the EERA Joint Programme Concentrated Solar Power (JP CSP).

Launched in 2015 at the opening of the COP 21 in Paris, the Mission Innovation initiative aims to strengthen the financing of research and development for decarbonised technologies in the energy field. In 2018, it brings together 24 members (23 states and the European Commission) which together account for more than 80% of global energy R&D efforts. In 2016, the initiative gave concrete expression to the commitments to double public funding in this area made at a ministerial meeting in San Francisco in June 2016: a global increase from 15 to 30 billion dollars per year by 2021. Within this framework, France is concentrating its efforts on renewable energies and energy efficiency, relying in particular on the increased power of the future investment programme (launch of PIA3 in particular).

In addition to national commitments, the initiative also aims to strengthen international cooperation on low-carbon innovation through eight "innovation challenges" for enhanced collective action: access to off-grid electricity, smart grids, advanced biofuels, carbon capture/storage and recovery, materials for energy, renewable heat and cooling, direct conversion of solar energy into chemical compounds, and clean and renewable hydrogen. These challenges give rise to a variety of activities, such as scientific conferences, publication of technology roadmaps, organisation of international innovation competitions, etc.

The Mission Innovation initiative is also complementary to private sector initiatives, notably the Breakthrough Energy Coalition, a group of private investors from various countries, coordinated by Bill Gates, who wish to encourage innovation in low-carbon energy technologies through long-term risk-taking investments.

During the first phase of MI, France was a member of the MI steering committee and the Business and Investor Engagement Sub-Group and co-led with India the challenge "innovation in off-grid electricity access from renewables". Since their inception, France supported the innovation challenges on carbon capture, utilisation and storage and hydrogen. France supported the launch of the second phase of MI and has declared its interest to contribute to the missions most relevant to French priorities for the energy transition, the Zero-Emissions Shipping Mission and the Hydrogen Initiatives. France actively participates in two main initiatives of the Clean Energy Ministerial – ISGAN (smart grids) and ZEV (zero emissions vehicles) – and recently joined the NICE Future (Nuclear Innovation for Clean Energy Future) Initiative. France has co-led a campaign on near-zero emissions buildings under the Global Alliance for Buildings and is a member of the Energy Efficiency Hub.

France supports the international exposure of its public research organisations, access to an international network of specialists; the possibility for researchers to collaborate, exchange and benchmark their work, stimulate the creation of new projects outside of technical collaboration programmes and access economic, technical, and political information at the international level. Regarding this it is worth to mention that CNRS facilitated Europe-wide collaboration among CSP researchers through SOLLAB, connecting the major EU laboratories in France, Germany, Spain, and Switzerland (CNRS-PROMES, DLR, CIEMAT-PSA and ETH respectively). Furthermore, Gilles Flamant, former Director of CNRS-PROMES was elected as new Chair of the SolarPACES Executive Committee for the next 4-year term, at the 101st Ex-Co meeting held October 4th, 2021.

6.3.2 Overview of the context for industry

The desk research and the preliminary interviews helped ESTELA refine its understanding of the energy context in France. The following subsections were enriched thanks to ESTELA's own desk research and inputs from five stakeholders: CNRS, CEA, ENGIE, TotalEnergies and RTE, which all have been very helpful, providing the consortium with a list of stakeholders to contact and sketching out a thorough context of energy policy in France.

6.3.2.1 Energy policies and the place of STE in the French landscape

6.3.2.1.1 Current energy mix in France

France is highly dependent on fossil fuels, i.e., solid fossil fuels, oil, petroleum products and natural gas, which altogether represent 60% of the total final energy consumption in 2019, as shown in Figure 39[125]. Table 32 shows that households is the sector with the highest share (i.e., 30,2%) in the final energy consumption of France, followed by transport (i.e.,

[125] *EU Commission, DG Energy, Unit A4 - ENERGY STATISTICS, Energy datasheets: EU countries, France*

29,8%) and industry (i.e., 20,2%). Figure 40 presents in detail the breakdown of energy sources used by sector[126].

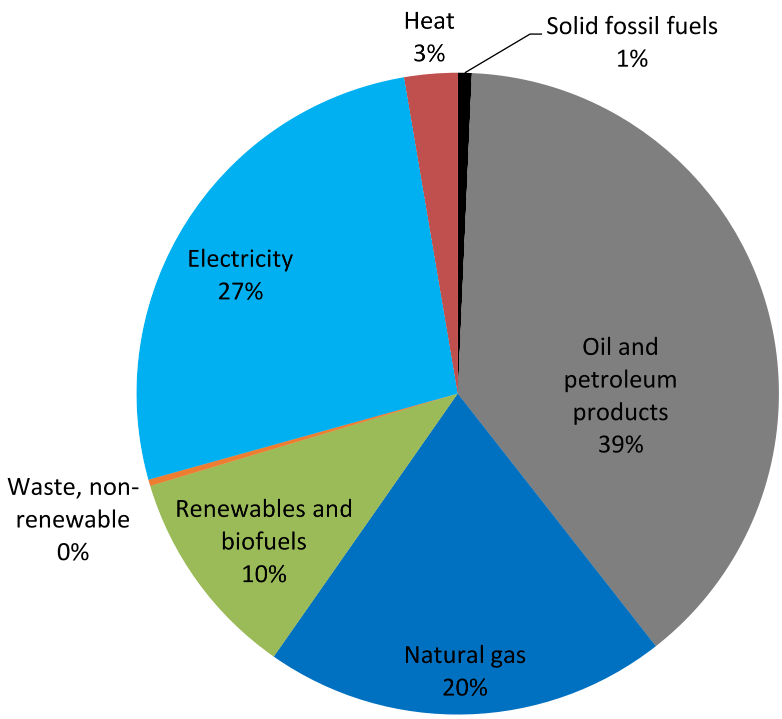


Figure 39: Percentage breakdown of final energy consumption by fuel in France, 2019 (Source: EU Commission, DG Energy)

Sector	Final energy consumption	
	ktoe	Share
Industry	25945,0	20,2%
Transport	38218,7	29,8%
Commercial & public services	20340,9	15,9%
Households	38710,7	30,2%
Agriculture & forestry	4169,7	3,2%
Fishing	333,5	0,3%
Other	597,2	0,5%
Total	128.315,6	100,0%

Table 32: Breakdown of final energy consumption by sector in France, 2019 (Source: Eurostat)

[126] *Eurostat, Energy balance sheets: France, January 2022 edition*

In the three most energy-consuming sectors (Figure 41), electricity represents more than one third of final energy consumption in households, followed by natural gas (27,8%) and renewables (22%). Oil and petroleum products are dominantly consumed in the transport sector, while fossil fuels (i.e., solid fossil fuels, oil, petroleum products) account for more than half of the energy consumption in industry, followed by electricity with a share of 35,1%. Moreover, heat consumption represents 6,4% of the final energy consumption in the industry sector.

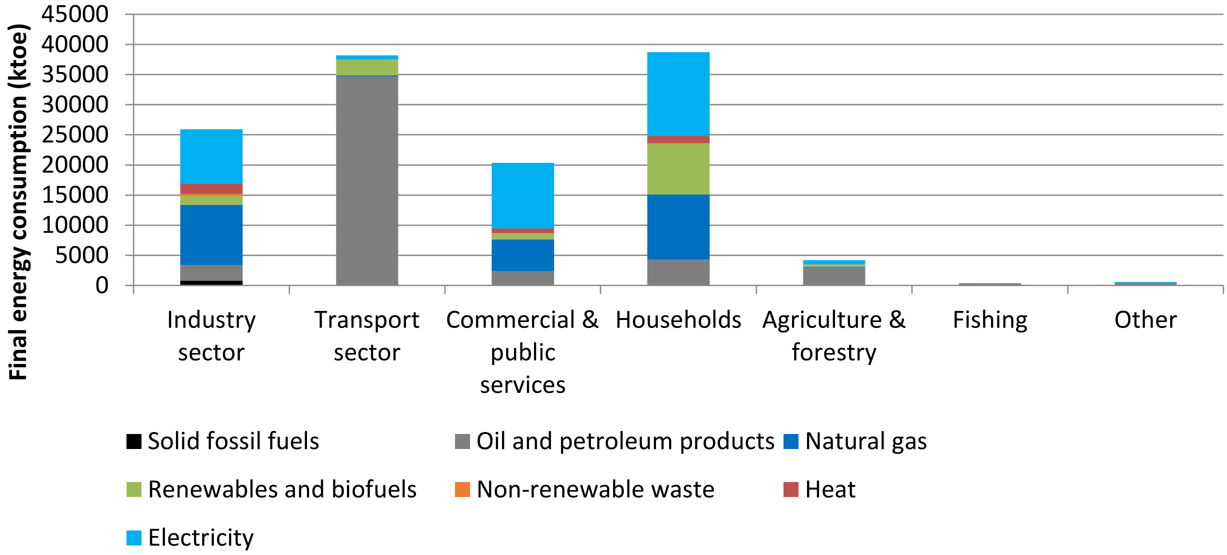


Figure 40: Breakdown of energy sources in final consumption by sector in France, 2019 (source: EU Commission, DG Energy)

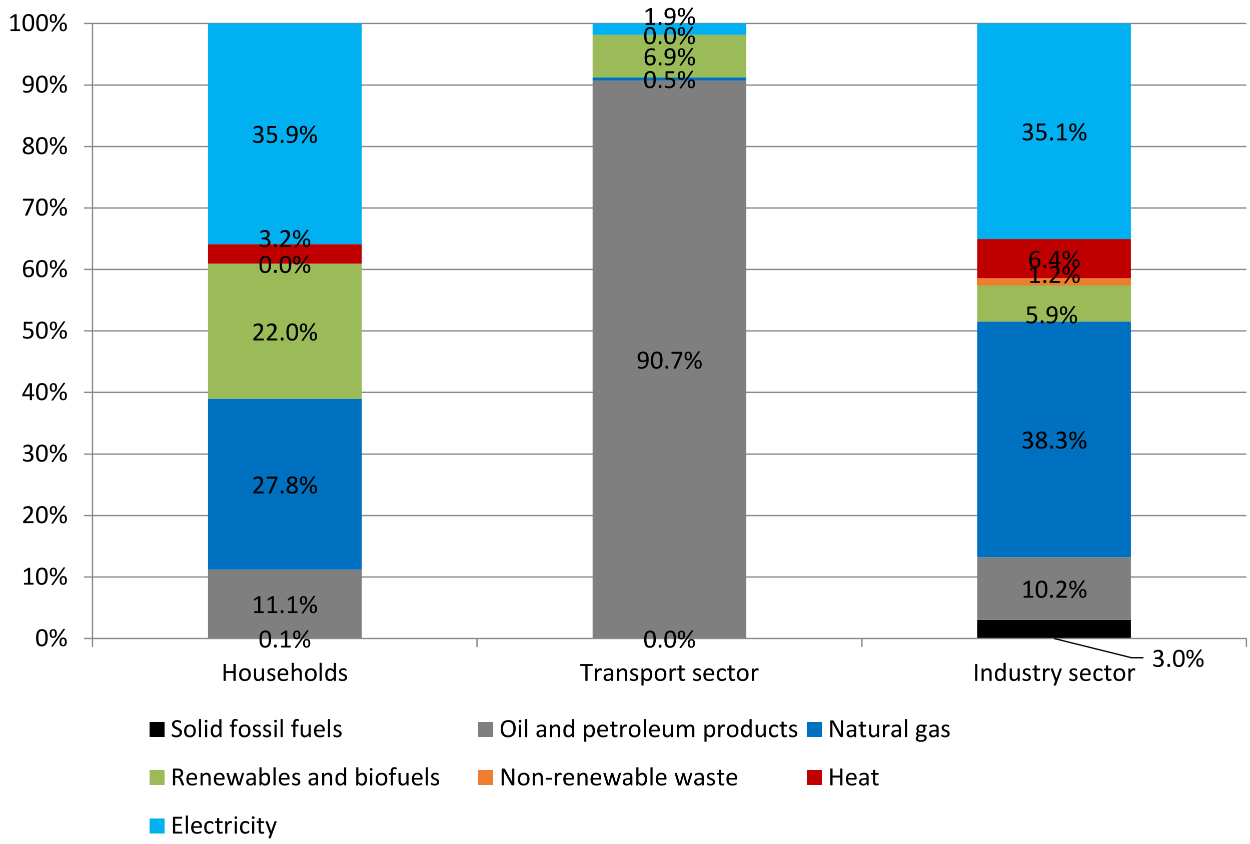


Figure 41: Share of energy sources in three main consuming sectors

In 2020, nuclear represented almost two thirds of electricity generation in France, as shown in Figure 42. Renewables account for 23,6% of total electricity generation, with hydro having the highest RES share (equal to 12,7%), followed by wind (7,9%) and solar (2,9%).

In 2019, the total installed capacity for electricity production in France was 136.242 MW, with the percentage breakdown by source shown in Figure 44. Nuclear represents 46% of installed capacity for electricity production. Hydro and wind account for the largest share of installed RES, which combined represent 31% of total installed capacity, with solar having a share of 8%.

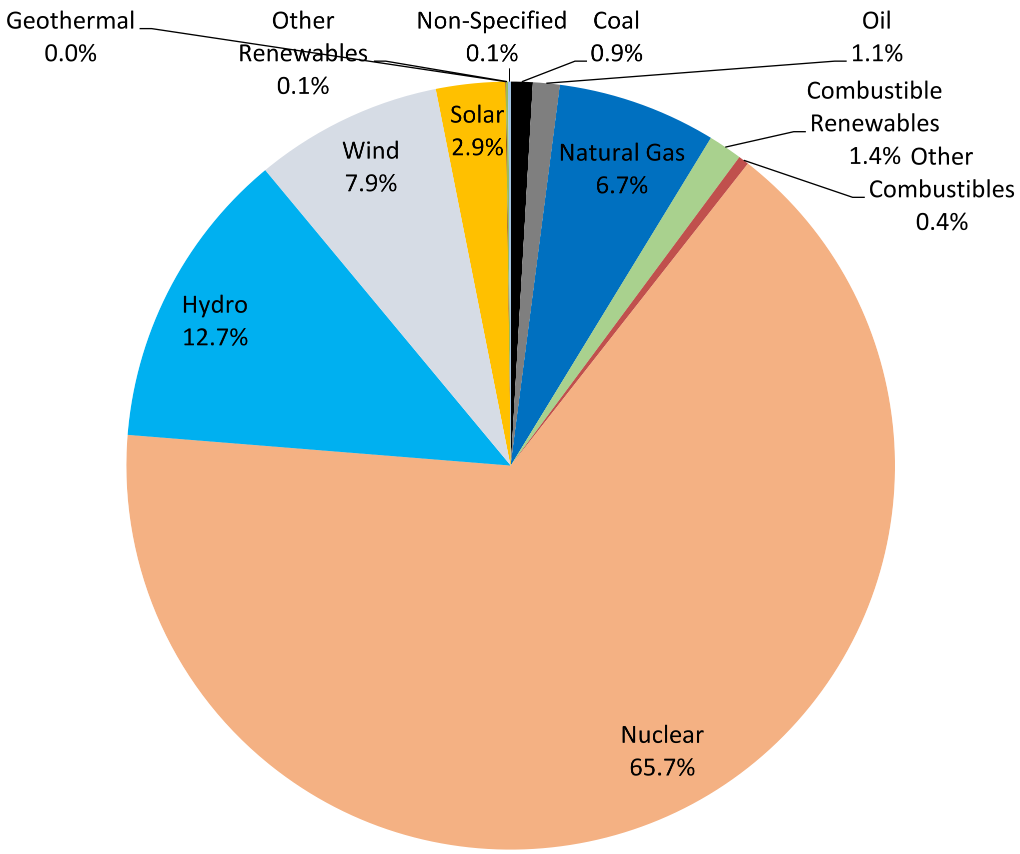


Figure 42: Electricity generation by source in France, 2020 (source: IEA)

In 2019, the total installed capacity for electricity production in France was 136.242 MW, with the percentage breakdown by source shown in Figure 44. Nuclear represents 46% of installed capacity for electricity production. Hydro and wind account for the largest share of installed RES, which combined represent 31% of total installed capacity, with solar having a share of 8%.

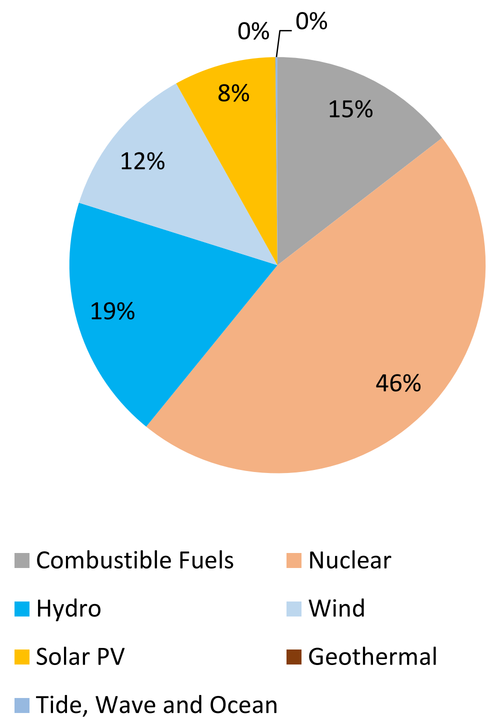


Figure 44: Percentage breakdown of installed capacity for electricity production by source in France, 2019 (source: EU Commission, DG Energy)

Figure 43 depicts the monthly breakdown of electricity production by source from January 2019 to March 2021 in France, clearly showing the dominant role of nuclear power plants.

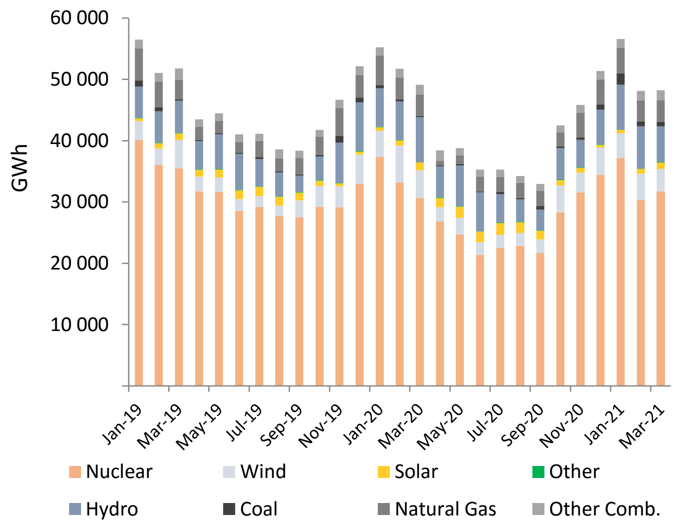


Figure 43: Monthly electricity production in France (source: IEA)

The French electricity transmission system includes interconnections with Spain, the UK, Belgium, Luxembourg, Germany, Switzerland and Italy. The interconnections balance in

2020 (Table 33)[127] shows that France was a net exporter of electricity, with quantity of exported electricity more than three times as much the quantity imported.

Interconnections balance in 2020	
Electricity imports [GWh]	19.820,7
Electricity exports [GWh]	64.408,8
Net exports [GWh]	**44.588,1**

Table 33: Electricity imports and exports in France, 2020 (source: IEA)

6.3.2.1.2 The French NECP and the potential for STE

The French national contribution to renewable energy, submitted in the National Energy and Climate Plan (NECP)[128] aims at 33% renewable energy in its energy mix in 2030. More specifically, France aims at reaching shares of renewable energy of 40%, 38%, and 15% respectively for electricity, heating and cooling and transport sectors, with a strong commitment related to the further deployment of wind power, both onshore and offshore, and a five-fold increase in photovoltaic energy by 2030. The NECP includes information on how the risks of climate change could affect future energy supply and further information on the benefits of adaptation for energy efficiency. This, therefore, implies a fundamental transformation in sectors that are still heavily dependent on oil, gas, fossil fuels, and sometimes even coal, such as in the thermal management of buildings, transport, industry, and construction.

The Government aims to create a stable and simplified legal framework for permitting, enabling the reduction of the permitting duration and giving reasonable time for project development, considering the environmental impacts of projects, including a comprehensive impact assessment in the energy reduction. The policies and measures proposing clear objectives are well detailed and contribute to renewable energy by covering the European expectations.

The targets in terms of energy security are the phasing out of coal power plants and decreasing the share of nuclear energy, while putting an end to sales of GHG-emitting vehicles as of 2030 will enable all territories to benefit from alternative mobility services to individual car use. This will also contribute to unleashing innovation, controlling the demand for mobility, developing low-emission vehicles (including river, sea, and air), and improving the energy efficiency of the fleet by relying on the alternative fuels market.

An analysis of the internal energy market will guide the allocation of the use of RES to the various sectors (electricity, improvement of the global demand response in the next decade), besides the planning of the necessary interconnections with neighbouring countries.

The intensification of the regional cooperation is already taking place with Spain and Portugal at the R&I level and announced to be expanded to new industry relevant areas.

This projected outlook in the NECP leaves no room for the integration of CSP into the electricity system in the short term. However, the French NECP recognises the major

[127] *https://www.iea.org/data-and-statistics/data-product/monthly-electricity-statistics*

[128] *https://energy.ec.europa.eu/system/files/2020-09/fr_final_necp_main_en_0.pdf*

potential of solar thermal energy in the collective sector (including on the grid), the tertiary sector and in industry. Importantly, it considers that the sector (currently based on export business) can increase the capacity of installed solar thermal equipment by a factor between 3 and 4 compared to the 2019 levels. In this direction, the French NECP introduces specific targets for CST applied to industrial process heat. Notably, targets of 150.000 m^2 of facilities (around 50 solar power plants) and 300.000 m^2 of facilities (around 100 solar power plants) are set for industrial heat production from solar thermal sources in 2023 and 2028 respectively, based on the Multiannual Energy Plan for the period 2019-2028 (PPE 2)[129].

6.3.2.1.3 Industry stakeholders

While the NECP doesn't fully recognise the potential of STE, the industry has taken first steps towards the CST development in France, as shown in Table 34. The construction for the first and only commercial CSP plant eLLO (Figure 45), located in Pyrénées-Orientales, France, started in 2016 with the plant becoming operational in 2019. This 9-MW Fresnel plant has a 4-hour storage system at full capacity and output is estimated at 20 GWh, which equates to the mean electricity consumption of 6.000 households in France. SUNCNIM, which designs, builds and operates solar plants with energy storage for the production, has designed, built and operates the eLLO project, which beneficiates a 20 years' power purchase agreement. The plant is world's first Fresnel type thermodynamic solar energy plant with energy storage.

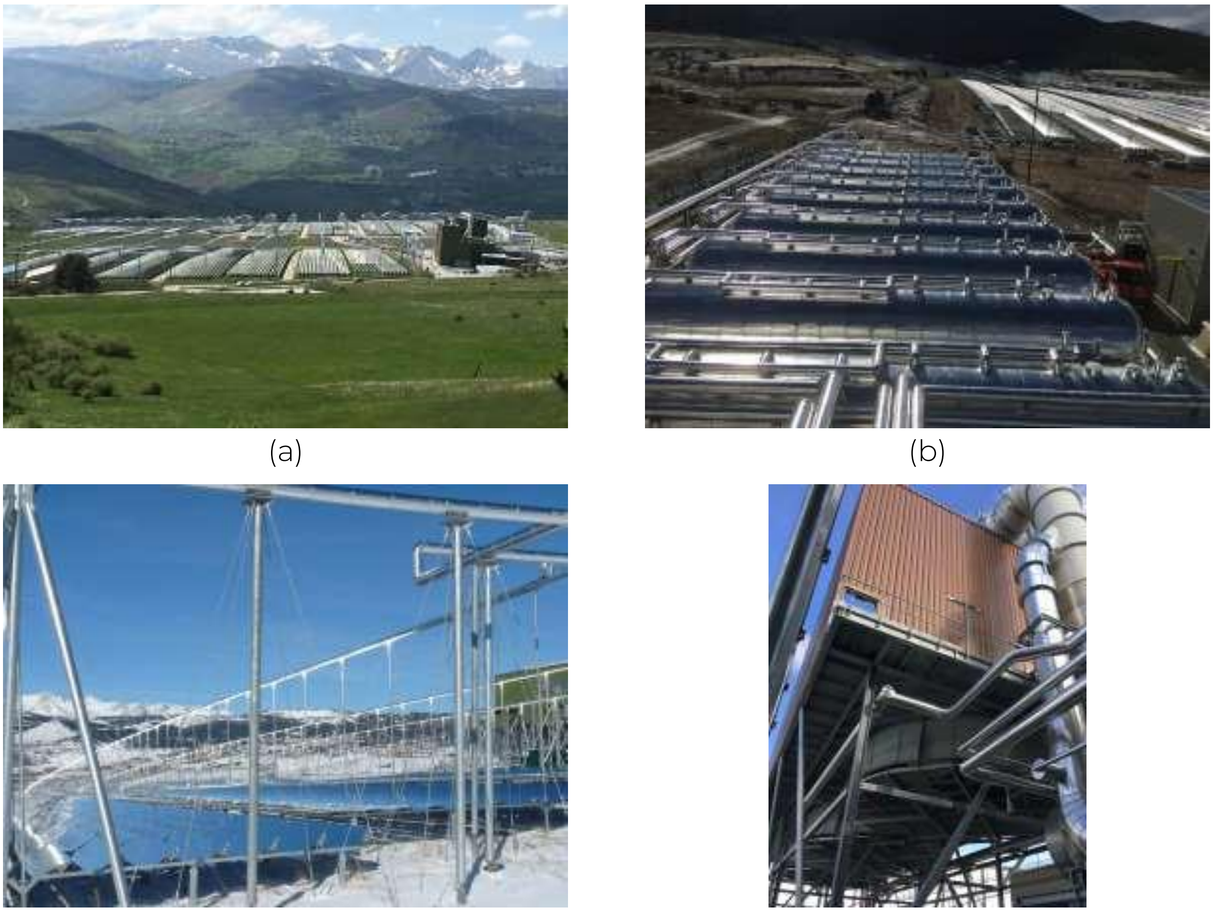
The solar collector is composed of 95.200 mirrors fitted to 23.800 collector panels covering a total surface area of 153.000 m². It is the world's first LFR CSP plant with an energy-storage of 4 hours capacity. The storage technology is steam accumulator storage tanks (9 tanks).

Company name	Company website	Company expertise
ENGIE	https://www.engie.fr	Plant developer/owner
EDF Group	https://www.edf-renouvelables.com/en/	Plant developer/owner (EDF Renewables develops, builds and operates clean energy power plants)
SUNCNIM	https://www.suncnim.com/en	Technology provider/ plant developer
ALSOLEN	https://www.alsolen.com/en	Plant developer
AERTELIA	https://www.arteliagroup.com/en	Consulting, engineering and project management
AZOLIS	https://azolis.com/en/	Development, financing, engineering, construction and maintenance of plants
HELIOCLIM	http://www.helioclim.fr	Plant developer (solar cooling + ship)
IDHELIO	http://www.idhelio.com	Plant developer (LFR + TES)
EMS Focus	https://www.emsfocus.fr	Plant developer (PTC)

[129] *https://www.ecologie.gouv.fr/sites/default/files/0-PPE%20English%20Version%20With%20Annex_0.pdf*

Company name	Company website	Company expertise
INDDIGO	https://www.inddigo.com	Energy Consulting
KYOTHERM	https://www.kyotherm.com/fr/	ESCO (solar heating/cooling – ship)
NEWHEAT	https://newheat.com/en/	Solar heat but using flat panels
LACAZE ENERGIES	https://www.lacaze-energies.fr	Solar heat boilers
SUNTI	https://www.sunti.fr/fr/	ESCO (Sunti designs, finances, develops and operates its own plants and sells solar heat for industrial applications and district heating)
TECSOL	https://www.tecsol.fr	Engineering service company (flat solar heating and cooling)

Table 34: Industry stakeholders



(a) (b)

(c) (d)

Figure 45: eLLO CSP plant: (a) General view, (b) 9 storage tanks, (c) Linear Fresnel solar collectors, and (d) Dry-cooler

6.3.2.1.4 Six scenarios for the electricity sector of France

France is looking ahead to achieving the 2050 targets, working on the development of decarbonisation on the basis of the NECP commitment, reinforced by the study carried out by RTE that includes the new energy pathways to achieve carbon neutrality by 2050, entitled "Futurs énergétiques 2050"[130].

The RTE study on the generation mix scenarios, requested by the Ministry of Ecological Transition (MTE), follows the strategy of the Energy and Climate law adopted in November 2019, the Energy and Climate Planning (ECP)[131], and will have to set the broad objectives of the Multiannual Energy Plan (PPE 2) and the National Low Carbon Strategy (SNBC)[132] that has been elaborated based on the same energy and climate scenarios, providing a consistent technical background. These three documents will thus form the French energy and climate strategy, a law that must be adopted before July 1st, 2023.

The relevant RTE report, initially published in October 2021 and updated in February 2022, analyses six scenarios with various levels of RES penetration in the electricity mix, as shown in Table 35. Specifically:

- Scenario M0 considers a fully renewable energy system by 2050 by phasing-out nuclear power plants and accelerating the deployment of solar, wind and marine energies.
- Scenario M1 assumes the fast deployment of distributed renewable generation, mainly driven by solar power and supported by existing nuclear power (13% in the electricity mix).
- Scenario M23 is also based on high penetration of RES (87%), driven notably by the large-scale deployment of onshore and offshore wind farms.
- Scenario N1 foresees the stepwise development of new nuclear reactors in pairs on existing sites every five years starting in 2035, combined with the deployment of renewables to counterbalance the phase-out of second-generation nuclear plants.
- Scenario N2 follows a faster development of new nuclear reactors compared to scenario N1, i.e., a pair of new nuclear reactors every three years from 2035 with a gradual ramp-up, while slowing down the deployment of RES technologies.
- Scenario N03 considers a 50%-50% share between RES and nuclear in the generation mix in 2050, assuming that new nuclear capacity is added on top of existing reactors whose lifetime is extended beyond 60 years.

Scenario	Description	Share of RES	Installed capacity in 2050 (in GW)				
			Solar	Onshore Wind	Off-shore wind	Existing nuclear	New nuclear
M0	100% RES	100%	208	74	62	-	-

[130] *https://assets.rte-france.com/prod/public/2021-12/Futurs-Energetiques-2050-principaux-resultats.pdf*

[131] *LOI n° 2019-1147 du 8 novembre 2019 relative à l'énergie et au climat (1), https://www.legifrance.gouv.fr/loda/id/JORFTEXT000039355955/*

[132] *https://www.ecologie.gouv.fr/sites/default/files/Projet%20SNBC%20EN.pdf*

Scenario	Description	Share of RES	Installed capacity in 2050 (in GW)				
			Solar	Onshore Wind	Off-shore wind	Existing nuclear	New nuclear
M1	Distributed renewable energy	87%	214	59	45	16	-
M23	High RES	87%	125	72	60	16	-
N1	RES + new nuclear	74%	118	58	45	16	13
N2	RES + faster nuclear development	63%	90	52	36	16	23
N03	50% RES + 50% nuclear	50%	70	43	22	24	27

Table 35: Generation mix scenarios in 2050 (source: RTE)

As pointed out above, France has set the objective of increasing the RES share in electricity generation to 40% by 2030 in its NECP. To achieve this target, PPE 2 foresees the substantial contribution from both floating and fixed offshore wind power, which is perceived as an innovative and job-creating sector. In this direction, France has been investing significantly in financing wind technologies, demonstrators, and pilot farms, three of which will be in operation in the Mediterranean by 2023-2024. France's objective is to conduct an industrial plan to become a key international leader in the production of floating wind solutions.

6.3.2.1.5 Decarbonisation policies and measures beyond the electricity sector

The analysis of the economic, social, and environmental impact demonstrates the benefits for the French economy from implementing this RES deployment strategy[133]. The measures to achieve the 2050 targets include the support to those most affected by the energy transition, competitiveness of the businesses sector, protection of the purchasing power of consumers living in energy poverty, and identification of the professional skills required by the energy sector. Although net job creation is certainly positive, the impact of the transition will range among sectors. These challenges will require adaptive strategies that combine forward planning with mechanisms to safeguard workers' professional futures. In this direction, inclusiveness is the necessary tool for effective governance, engaging labour and employer unions with regional and national authorities to produce a strategic plan for employment and skills transition.

The development of the renewable energy plan in France represents a major investment for the country. There are major challenges to be tackled in the future energy plan, aiming to reduce fossil fuel consumption and ensure a clear, fair, and sustainable energy transition, a firm commitment of the government to increase RES and reduce dependency on oil and gas imports. These elements would contribute to a socially just

[133] *https://www.entreprises.gouv.fr/fr/crise-sanitaire/france-relance/decarbonation-de-l-industrie*

energy transition, integrating skills and training aspects and considering their social and employment impact.

The planned policies and measures for the decarbonisation dimension involve the improvement of energy efficiency and the development of renewable energy in different sectors:

- Transport: measures to improve the energy efficiency of new road transport vehicles, encourage purchasers to buy the most efficient low-emission vehicles and promote the development of alternatives and biofuels.
- Residential and tertiary: measures to promote the use of efficient heating equipment and improve the energy efficiency of other types of equipment, aiming at increasing the thermal performance of the building envelope, reducing emissions and using the least carbon-intensive energy sources. Improving the energy performance of farms and maintain and increase carbon stocks on plots of land and in the soil, with measures and policies in the agricultural sector aim to improve the control of fertilisation, regarding forests, the measures in place seek to promote carbon sequestration in the forest ecosystem through better forest management and to develop the use of bio-sourced products.
- Industrial sector: France's policy to reduce greenhouse gas emissions is mainly based on limiting the emissions of the most emitting industrial plants through the European Emissions Trading Scheme.
- Energy: cross-cutting measures that contribute to containing energy demand and facilitate the further deployment of RES.
- Waste treatment: waste reduction is based on prevention, the implementation of extended producer responsibility schemes, encourage sorting to increase the quantities of waste recovered, and fiscal measures to limit the disposal of waste.

Common issues within the political agenda remain the independence from fossil fuels, the need for massive RES development, and bringing France's competitiveness on renewables to the same level as other European countries. In particular, the pathway to "greening" the electricity system and electrify the transport sector considers the increase of solar power combined with doubling the offshore wind power.

6.3.2.1.6 Public debate and social acceptance

There is an ongoing public debate related to the implementation of nuclear power in France and the needs of new storage sites for accumulated radioactive waste. Nuclear power is the main source of electricity production in France, considered as an energy source that emits very few greenhouse gases (unlike coal or hydrocarbons) but generates radioactive waste not only as by-product from nuclear reactors, but also while decommissioning and dismantling nuclear reactors and other nuclear facilities.

According to the latest national inventory of radioactive materials and waste published by the National Agency for Radioactive Waste Management (Andra)[134], France had 1.64

[134] *https://international.andra.fr/*

million cubic metres of radioactive waste at the end of 2018[135]. Solutions used over the years for nuclear waste management include the following:

- Ocean dumping was the first solution used by 14 countries, including France, to deal with the accumulation of nuclear waste. In 1993, the signatories of the London Convention on the Prevention of Marine Pollution decided to permanently ban the dumping of radioactive waste but the waste that has been dumped remains on the ocean floor.
- Although 90% of the radioactive waste produced in France now has a solution for final surface storage, the growing volume of waste poses a problem for the future. According to Andra's latest inventory, the volumes already stored increased by 30,000 m^3 during 2018.
- Research is currently underway at Andra to increase the capacity by 250,000 m^3. The site could reach saturation around 2028-2029, due to the upcoming dismantling of nuclear installations.
- Storage where waste is placed in surface or shallow facilities for a limited period before it is disposed of. This storage is a temporary solution for managing radioactive waste. This waste is therefore conditioned and stored by its producers until a final management solution is found.

The question emerging in the political and public debate is the manageability of nuclear waste, which was raised in the public consultation "*Commission nationale du débat public*" (National Commission for Public Debate)[136]. The results of this public debate relating to the 5th edition of the national plan for the management of radioactive materials and waste (Plan national de gestion des matières et déchets radioactifs, PNGMDR) were presented on 25 November 2019[137]. This debate also spreads across the various political parties while the original decisions about the massive nuclear engagement were taken in France without any public consultation in the early '70s.

Beyond the persistence of opposing and clear-cut opinions, particularly on the use of nuclear energy and nuclear waste management about the Cigéo deep geological disposal project[138], these debates introduce ethical arguments related to the legacy to future generations, governance and citizen mobilisation. As reported in the results of the public debate on the fifth edition of PNGMDR, living in a balanced environment that respects health is a right, as also participating in the elaboration of public decisions that have an impact on the environment. These indicate the need to rethink the links between the relevant stakeholders, especially those of civil society with institutional and economic actors involved in the management of waste and radioactive materials, and more generally in the choices of French energy policy.

Although the management of radioactive waste is at the heart of environmental concerns which were originally focused on nuclear waste, today the public debate embraces also

[135] *https://inventaire.andra.fr/sites/default/files/documents/pdf/fr/andra-maj_essentiels_2020-web.pdf*

[136] *https://unfccc.int/sites/default/files/567.pdf*

[137] *https://pngmdr.debatpublic.fr/*

[138] *https://fr.wikipedia.org/wiki/Cig%C3%A9o*

the waste produced by RES as these are promoted by the French energy and climate strategy. For example, deploying wind farms in France further implies promoting their acceptance by the society at large and thus overcoming the economic, social and environmental obstacles associated with wind turbines. Projects are currently being developed to design 100% recyclable thermoplastic-based wind turbine blades and, above all, to prove their technical relevance and viability with a response within 3 years. When it comes to the energy transition, it is nevertheless important to discuss and understand social acceptance or opposition to renewable energy projects. Today, there are already nearly 5,000 jobs linked to marine renewable energies in France's territory and the Government intends to develop a strong floating wind energy sector, anchored in the territories and create jobs. To develop wind energy with due respect for the environment, the creation of the National Offshore Wind Observatory is intended to provide input for future offshore wind development planning. Its objectives are twofold: to enhance existing knowledge and to launch new knowledge acquisition programmes in order to ensure that biodiversity issues are properly taken into account in the deployment of offshore wind farms[139].

Ecological movements are present also in France, as in most European countries, while the level of social acceptance depends on the type of renewable technologies to be introduced in the country and the degree of involvement of the population in the political debate. The establishment of nuclear power in France, during the beginning of the 1960s, had a strong political impulse characterised by the non-involvement of the population in its installation, and in this context, it is pertinent to examine how the public perception and social acceptance have been changing over the years[140].

Driven by the pacifist and intellectual mood of the 1960s and led mostly by groups of young philosophers, the first anti-nuclear organisation was founded when the French government announced plans to test nuclear weapons, experiencing the most intense anti-nuclear movement, experiencing a growing strength that saw France become one of the world's leading and most prominent nuclear energy-power countries in the 1980s.

The deployment of nuclear power in France has been dominantly based on political decision-making, even when the first anti-nuclear protest saw 15,000 people descend to demonstrate opposition to the Fessenheim nuclear power plant in 1971. Although the organisation gained a lot of public attention, it was unable to exert much political power over the country[141].

Activists in France did not have the power to intervene in regulatory issues and the anti-nuclear movements thus lacked a solid political base, even as demonstrations began to involve an ever-increasing number of protesters, up to 60,000 in 1977 against the Creys-Malville nuclear power plant, experiencing police repression and defeat.

France was barely affected by the radiation of the Chornobyl accident. On the contrary, Germany was affected to a greater extent and this highly discouraged the growth of

[139] *https://bilan-electrique-2020.rte-france.com/wind-power/?lang=en#*

[140] *D. Nelkin and M. Pollack, "Ideology as Strategy: The Discourse of the Anti-Nuclear Movement in France and Germany," Sci. Technol. Hum. Val. 5, 3 (1980).*

[141] *H.Kitschelt, "Political Opportunity Structures and Political Protest: Anti-Nuclear Movements in Four Democracies," Brit. J. Polit. Sci., 16 57 (1986).*

nuclear power in the country. The resources and economic cost of nuclear power in France played an influential role in halting the anti-nuclear movement in France by the end of 1977. Due to the failure of the French anti-nuclear movement, France has now become one of the major countries that have nuclear power[142].

Years after the closure of the Fessenheim power plant, pro-nuclear activists have taken action, reflecting the resurgence of a debate already known in France, which is stirring up the French political, scientific and social world. There is also a resurgence of the nuclear lobby not to lose this industry which poses the question “can nuclear energy be an ally in the fight against global warming?”.

There is a link between the level of education, energy issues, and acceptance of nuclear energy. Awareness of the physical limits of renewable energies (such as solar and wind) contributes to the acceptance of nuclear energy. More concrete knowledge of nuclear energy is provided by the habits of those living near a nuclear power plant, leading to the common view that it is safer to operate and has economic benefits.

While nuclear power still benefits from strong social acceptance, it seems that it is an issue extending from the originally nuclear power to other technologies and infrastructures.

6.3.2.2 The industrial perspective for CST in France

The industry sector in France accounts for 20% of its GDP[143], 20% of total energy consumption[144] and 22% of total greenhouse gas (GHG) emissions[145]. In the short and medium-term, the benefits of energy efficiency towards decarbonisation are cost savings due to the reduction of primary fuels consumption and additional protection to companies regarding the dependency on fossil fuels and energy price volatility. Two major approaches have been put in place to reduce CO_2 emissions from industry: on the one hand, support for industrial investments to improve energy efficiency and the development of industrial processes and, on the other hand, support for the decarbonisation of industrial process heat.

Since 2000, the decline of industrial emissions has been driven by improvements in the carbon intensity of production processes and the level of productivity; this decline was due to the technical performance improvements used in the investments to reduce pollution and improve manufacturing processes[146]. The likelihood of making further decarbonisation investments also increases depending on the size of the company, its pace of transition towards digitalisation, its impact on a wider decarbonisation objective, the company's image, its positioning towards its customers and, last but not least, from the level of external funding it achieves.

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[142] *J. Chenevey, "French Nuclear Phaseout," Physics 241, Stanford University, Winter 2017.*

[143] *https://www.cia.gov/the-world-factbook/countries/france/*

[144] *Eurostat, Energy balance sheets: France, January 2022 edition*

[145] *https://www.climate-transparency.org/wp-content/uploads/2020/11/France-CT-2020-WEB.pdf*

[146] *https://www.tresor.economie.gouv.fr/Articles/2021/10/07/decarbonising-industry-in-france*

The essential factors for further investments are therefore:

- The energy mix: electrifying and integrating renewable and recovered energy sources.
- Energy efficiency: optimising energy sources.
- Material efficiency and recycling: using less or more recycled material.

This is why the decarbonisation of the heat consumption of industrial processes is the second priority. Therefore, the new goal set for 2030 is to start new projects for producing green hydrogen and new fuels, having in mind the different types of storage facilities (among which thermal energy storage) as well as the transportation of fuels.

Due to the fact that such projects will have different needs for heat, the industries can be split in the following categories, depending on the temperature needed for the respectively processes:

- High temperature heat: Up to 800°C–1000°C for metal, steel, aluminium, iron, cement, glass, energy and gas industries.
- Low to medium temperature heat: For applications with low (< 150°C) to medium (150°C – 400°C) temperature requirements, such as chemical industry, oil and refinery business, and fertiliser industry.

The decarbonisation of industries is the hardest part of the process that must run faster to reach the objectives and goals proposed by the EU strategies 2030-2050. France's National Low-Carbon Strategy (SNBC), adopted in March 2020, sets target caps for industrial GHG, and a number of tools, including carbon pricing and public support for decarbonisation, are being used to meet these targets. As part of its national strategy, the Government has made it a priority to decarbonise industry by developing a French electrolysis industry. In 2020, the first call for projects was launched for the production of heat from biomass for industrial use. It concerned both projects for the installation of new equipment and the conversion to the biomass of existing installations using fossil fuels, the aim being to facilitate the transition to low-carbon industrial heat and the use of biomass rather than coal, oil, or gas. Given the quantity and quality of the projects that this scheme has enabled to emerge, this call for projects has been renewed in 2021.

The country is lacking industrial initiatives related to CST at national level, since it is rather seen as export business opportunity by French companies. Towards this direction, ADEME has a role to play in promoting and financing RES projects, from research to implementation, in its areas of action. More specifically, ADEME has 16 points of presence in France (3 sites for central services and 13 regional offices) and 7 points of presence overseas (4 regional offices and 3 representations)[147], providing expertise and advisory services to businesses, local authorities and communities, government bodies and the public at large[148].

[147] *https://www.ademe.fr/lagence/notre-organisation/*

[148] *https://www.climate-kic.org/partners/ademe-french-environment-and-energy-management-agency/*

In 2016, the "Franco-German Office for the Energy Transition" (OFATE) has been strengthened in order to enable OFATE to be "up to the challenges of the growing cooperation in the field of energy between France and Germany".

The scope of action of the OFATE, initially articulated around wind and solar energy, has thus gradually expanded and now includes other sectors and energy sources, such as bioenergy, as well as cross-cutting topics relating to the energy transition in both countries (integration of renewables into the system and the market, flexibility, energy efficiency, etc.).

Among the missions of the Franco-German Office for the Energy Transition are:

- The exchange of knowledge between France and Germany.
- Monitoring developments in the sector.
- The organisation of Franco-German thematic conferences and events as side events of major fairs and seminars organised by OFATE.
- The organization of bilateral meetings between political decision-makers, facilitating the exchange between experts and the development of common public policies and joint projects.

The activities of the OFATE are financed equally by public funds and members' contributions.

This initiative is followed by various platforms such as the “Syndicat des Energies Nouvelles” representing the French companies involved in renewables that had left in the past little room to other technologies than wind and PV in the context of the future scenarios for the (national) electricity. Neither did the ecology supporting party in France EELV brought the issue of dispatchable RES into the debate.

6.3.2.3 Hydrogen strategy in France

In relation to the objectives set for the decarbonisation of the industry sector in France by 2050, hydrogen is presented as one of the renewables that would be most used in the production of steel, fertilisers, and the transport sector.

Given its low-CO_2 electricity mix, France has the potential to produce carbon-free hydrogen, commonly used in the petroleum and chemical industries for a total consumption in France of about 900,000 tons per year[149]. This is in contrast to the vast majority of carbonated hydrogen produced elsewhere, which generates around 9 million tonnes of CO_2 per year.

Low-carbon hydrogen has many applications in France, such as in the field of mobility, hydrogen provides clean and complementary solutions to electric mobility and thus makes it possible to develop clean mobility, one of the objectives of the energy transition. The French strategy to accelerate the deployment of carbon-free hydrogen was officially announced on 8 September 2020. With an overall budget of more than €7 billion up to

[149] *https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf*

2030, including €2 billion for the period 2021-2022, the National Hydrogen Strategy has very high ambitions to meet the following challenges:

- Environmental issues: providing many solutions to decarbonise industry and transport.
- Economic issues: offering the opportunity to create an industrial sector and ecosystem that will create jobs.
- Energy independence: to reduce the importation on hydrocarbons.
- Technological independence issues to enhance France's assets in the global competition.

PPE 2 (for 2019-2028), published on 23 April 2020, aims to improve the competitiveness of the French hydrogen industry by deploying solutions for the 2030-2040 timeframe. It targets industrial hydrogen, hydrogen for mobility and hydrogen for storage, and sets targets for increasing hydrogen consumption in each of these areas by 2023 and 2028.

The hydrogen strategy envisages the deployment of 6.5 GW of installed electrolysis capacity by 2030. France's ambition is to become a leading international supplier of high-performance, high-efficiency electrolysers with the reliability to enable industrial operation.

At national level, support instruments for the development of decarbonised hydrogen are foreseen up to 50 million euros per year as well as calls for hydrogen-based mobility projects, including a tracking system for carbon-free hydrogen in 2020.

Further initiatives consist in a study conducted with all stakeholders about the simplification and harmonisation of approval procedures for vehicles and the corresponding hydrogen refuelling solutions.

6.3.2.4 International cooperation as a wider source for renewable power in France

France is currently working towards the EU targets for carbon neutrality by 2050 by strengthening its international collaborations, while maintaining its technological leadership in EU on the nuclear sector with respect to both fission and fusion technologies.

In addition to the France’s established R&I collaborations at EU level, the industrial landscape in France is characterised by large players active in the world market of the energy sector in general, and of renewable technologies in particular. In this context, CST is viewed as an export business where French companies lead or participate in projects within and outside Europe. Large organisations in the energy sector of France are indeed global energy players that have the capacity and know-how to deploy RES projects of any type/technology. The specific technology to deploy depends on the framework conditions in a given country, e.g., the design of RES auction. Focusing on solar technologies, selected examples of projects include the following:

- EDF[150]: Boléro solar plant (146 MWp) in Chile, Zmorot solar plant (50 MWp) in Israel, and Toucan solar plant and storage site (5 MWp) in French Guiana.
- TotalEnergies[151]: Al Kharsaah solar power plant in Qatar, Shams CSP plants in the United Arab Emirates and the partnership with Adani Green Energy Limited to deploy solar projects of around 5 GW of in India.
- ENGIE[152]: Kathu CSP plant in the Northern Cape province of South Africa and the PowerCorner project for rural communities across Africa.

In spite of being a French multinational integrated oil and gas company, the projects put in place by TotalEnergies also cover the entire renewables value chain, starting from design, financing, and construction to operation of solar PV plants, with increasing installed capacity over the years, reaching 10 GW in 2021 compared to 0.7 GW in 2017. Such projects in India, Spain and Qatar demonstrate France's high potential in the international market and bring out the reasons why auctions in countries of interest are more favourable compared to France's domestic auctions. Furthermore, SunPower, as an affiliate of TotalEnergies active in the United States market, develops distributed PV solutions, including rooftop systems for residential, industrial and commercial buildings as well as solar carports. The presence of TotalEnergies in RES projects extends also to the Netherlands, and more specifically to the Zeeland refinery (jointly owned with Lukoil)[153], where 28,000 PV panels on an 11.5-hectare plot of land supply electric power of 12 MW for the self-consumption of the refinery.

The expansion of the export business by French companies is further demonstrated by EDF's activity beyond the EU borders. EDF Renewables (subsidiary of EDF) led the consortium (also comprised of Masdar and Green of Africa) selected as the successful bidder for the construction and operation (in partnership with MASEN) of the Noor Midelt hybrid CSP and PV power plant in Morocco[154]. In the U.S., EDF acquired of groSolar, a company that designs, develops, manufactures, and markets complete solar photovoltaic solutions for local authorities, businesses, and industry, while EDF Renewables is one of the largest RES developers in North America with 8 GW of wind, solar, biomass, biogas, and storage projects[155].

Moreover, the French NECP not only includes electricity interconnection targets that contribute to the energy and climate goals, but also acknowledges the particularly high importance of increasing interconnections with the Iberian Peninsula, with mutual benefits for France, Spain and Portugal. Besides interconnections with the latter two countries, further electricity system links with Italy, United Kingdom and Ireland are planned, while studies to strengthen interconnections with Germany, Switzerland, and Belgium are also foreseen in alignment with the NECP interconnection targets, the

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[150] *https://www.edf-renouvelables.com/en/project-development/solar/*

[151] *https://totalenergies.com/projects?category=1586&location=All*

[152] *https://www.engie.com/en/activities/renewable-energies/solar-energy*

[153] *https://zeelandrefinery.nl/en/home-english/*

[154] *https://www.solarpaces.org/morocco-pioneers-pv-to-thermal-storage-at-800-mw-midelt-csp-project/*

[155] *https://www.edf-re.com/press-release/edf-renewable-energy-acquires-grosolar/*

scenarios in the RTE study and MEP 2. The Ten-Year Network Development Plan assumes that France's interconnection capacity will double in 15 years, from around 15 GW today to almost 30 GW in 2035.

France has the potential to reach the EU targets by working both at national and regional level. This potential is currently reassessed at regional level, allowing to phase out certain technologies, while at the same time the Government is examining the best-fit clean energy technology replacements. Notably offshore wind is a major energy and industrial opportunity, and for this reason, the Government decided to sign an offshore sector deal with France's wind industry with a commitment to build a capacity of 40 GW offshore wind power by 2050, spread over 50 wind farms.

6.3.2.5 Energy regulation in France: a strategy to include flexibility

The Energy Regulatory Commission (Commission de régulation de l'énergie, CRE)[156] is the independent public body regulating the electricity and gas markets in France for the benefit of end consumers and in alignment with the national energy policy objectives.

In the light of the Russian invasion to Ukraine and its impact on the energy crisis, it is noted that France is highly dependent on fossil fuel imports. In this regard, diversifying the energy mix and further deployment of RES can contribute to reinforcing security of supply and mitigate the consequences from the political and/or economic crisis.

France plans to phase out coal and gas from the industry sector within 5 years[157], replaced by renewables. To achieve this however would require the existing legislative framework to be revised to simplify the permitting process of new RES projects, in order to allow reducing the construction time for new renewable plants from the current 6-8 years. Phasing out oil will undoubtedly take longer, with estimations of at least 10 years to achieve complete elimination from the energy mix.

France needs also to accelerate the transition to hydrogen for the transport sector, which contributes to 29,8% of final energy consumption. The French “hydrogen deployment plan for the energy transition”[158] already provides a comprehensive framework comprised of several objectives to support the deployment of hydrogen through power-to-gas and enable hydrogen use in transport. Measures to stimulate the deployment of hydrogen include[159]:

- Support for the development of hydrogen.
- Guarantees of origin for decarbonised hydrogen production.
- Financial incentives for the purchase of hydrogen vehicles.

[156] *https://www.cre.fr/en*

[157] *https://www.bfmtv.com/economie/entreprises/energie/sortir-du-charbon-et-du-gaz-macron-assure-que-la-france-peut-y-arriver-sur-le-quinquennat-a-venir_AV-202204220257.html*

[158] *https://www.ecologique-solidaire.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf*

[159] *https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20France%20%28ID%209473038%29.pdf*

- Standardisation of co-financing models for ecosystem deployment projects.
- Simplification and harmonisation of licensing and certification procedures for refuelling infrastructure.

Furthermore, the use of hydrogen for low-carbon heating and cooling in buildings is also seen as one of the eight innovation challenges in the French hydrogen plan.

It is therefore important that regulatory frameworks are in place to enable a flexible evolution of the network and allow a smooth transition, supported by:

- Local energy production, development of smart grids and self-production.
- Interactions between electricity, gas and heat networks ("power-to-gas" and "power-to-heat").

6.3.2.6 The energy transmission system in France: the role of RTE

The French TSO, RTE (Réseau de Transport d'Électricité), is responsible for the operation, maintenance and development of the largest high-voltage transmission system in Europe, which features more than 105.000 km of high and ultra-high-voltage lines and 50 interconnections with neighbouring European countries[160].

ESTELA conducted an interview with a representative of RTE, which confirmed that the currently RES discourse in France does not include CSP technologies and thermal storage. CSP wasn't considered in the PPE 2 (from 2019 till 2028), which sets the MW generation targets for energy production technologies in France, including numerous RES. However, if a push from industry is made, CSP might be considered in the future perspective covering time period from 2028 to 2035 and beyond.

The study "Futurs énergétiques 2050" carried out by RTE and extensively covered in section 6.3.2.1.4, was further discussed during the interview. The six scenarios analysed in the study represent various levels of RES penetration in the country's energy policy:

- The first scenario presents 100% renewables by 2050, proposing the replacement of existing nuclear reactors with photovoltaic, wind, and marine energy technologies.
- The second scenario proposes a combination of RES, with solar power taking the leading role, and existing nuclear power, without building new reactors.
- The third scenario presents a combination of RES, with onshore and offshore wind farms taking the leading role, and nuclear power, without building new reactors.
- Three other scenarios involving further development of nuclear power plants, with the share of RES increased in comparison with the current situation.

With respect to the reinforcement of international electricity connections, the RTE representative confirmed the economic interest to expand the link capacity level to 39 GW by 2050. Specifically, the interconnection projects have been classified into three packages:

[160] https://www.rte-france.com/en/about-rte

- "Package 0" includes the completion of the two ongoing projects with the UK, namely IFA 2 and ElecLink, and one with Italy, i.e., the Savoie-Piedmont project. The IFA 2 project was placed in service on 22 January 2021, increasing the interconnection and sustaining the energy transition between France and the UK, streamlining the use of generation sources as well as helping to provide security of supply for both countries, with the follow-up and enhancement of the first interconnection, called the IFA 2000, put into service as early as 1986. France-Italy interconnector between the Grande-Ile (Sainte-Hélène du Lac) and Piossasco (Turin) project, led by RTE and its Italian counterpart TERNA, involves the construction of new substations, and an underground high-voltage direct current (HVDC) line almost 190 km long. The new line will increase the capacity for trade between these two countries by 60%.
- "Package 1" includes all the interconnections already started with Spain through the Bay of Biscay line, with Germany and Belgium. The Bay of Biscay project involves creating a new interconnection between France - Cubnezais (near Bordeaux) to Spain, in Gatika (near Bilbao), and will be the first France-Spain interconnection that is partially underwater. Scheduled to be brought into service in 2027, will be the first France-Spain interconnection that is partially underwater, boosting the exchange capacity between the two countries to almost 5,000 MW.
- "Package 2" includes all remaining interconnection projects which have been subject to political, economic or technical conditions (Brexit, number of European subsidies…).

Recognised as a Project of Common Interest (PCI) by the European Union, the Celtic Interconnector project responds to the European challenges of energy transition and the fight against climate change by facilitating the evolution toward a low carbon electricity mix. It will contribute to more secure, sustainable, and affordable electricity. The Celtic Interconnector project, supported by RTE and its Irish counterpart EirGrid, will link the Knockraha substation (East Cork region in Ireland) to the La Martyre substation (Finistère). The aim is to create an HVDC line to allow direct electricity exchanges between the north coast of Brittany and the south coast of Ireland in 2026.

6.4 Key findings

6.4.1 R&I

French R&D activities about renewables stand out firstly by size and scope. France has a dynamic energy-related research, development and demonstration (RD&D) landscape, which is supported by active collaboration, strong integration and stable funding. The funding agencies, ANR and ADEME, work closely with ANCRE, which is the key alliance of research organisations and participates in the implementation of the national strategy and is active in the European Energy Research Alliance.

To strengthen the links and foster collaboration between public research institutes, academia and industry actors, France has promoted the creation of regional high-tech and innovation clusters. Regional clusters can serve as innovation platforms for collaborative projects between academia, public and private actors, including start-ups. With the right incentives to collaborate, they can help bridge the gap between labs and markets.

6.4.1.1 Focus on heat applications of CST

France's energy research community is present across the entire CST R&D value chain, and public sector actors are typically involved at least to some extent in all steps of technology development, from basic and applied research to demonstration.

Looking specifically into solar thermal research, they show a strong focus on technologies to produce thermal energy, to store it but with a nearly exclusive purpose of using it efficiently for industrial applications like heat pumps, boilers, and thermal exchangers.

On the one hand, CNRS-PROMES, being an organisation performing fundamental research, is mainly focused on developing research on next generation of CSP plants and solar thermochemistry. On the other hand, CEA-Liten, which is a public body performing applied research and developing demonstrators in collaboration with industry, is more concentrated on SHIP applications and integration of renewables at system level.

6.4.1.2 Good level of R&I collaboration

With industry: the R&D platform on solar thermal involves around 50 industrial partners, including major corporations like GDF Suez, Saint Gobain, TotalEnergies, and Renault all aiming to improve the performance of their industrial processes by optimising heat transfer and by introducing thermal storage systems.

Across the R&D community: French R&I structures are also well integrated in the international cooperation projects of the European Institutions.

6.4.1.3 Good level of funding

Due to the fact that CNRS (PROMES) and CEA (LITEN) as main R&D entities in France are to a large extent publicly funded, no decrease or stress on funding was identified beyond the usual arbitrage issues on research. Due to this structural positioning, these entities appear as close to political authorities resulting in a remarkable alignment of research activities on the political agenda.

So will the CNRS global budget of 3,82 M€ for 2022, increased by 3,5% compared to 2021. In this context the project did not identify an announced reduction of funding to the solar thermal sector well focused on heat.

6.4.2 Industry

6.4.2.1 Large players are focusing on CSP just as export business

French industry players such, as EDF Renewables and ENGIE are not only active, but also successful in tendering processes launched in so-called active CSP markets, e.g., Morocco, South Africa, Emirates, and Saudi Arabia.

The “French Solar Plan” was launched in 2017 by EDF (not a government, but EDF’s own “voluntary initiative”) with a budget of some 25 B€ over 15 years with a clear goal: make EDF PV leader in France with a 30% market share in 2035 and as such one of the world leaders in solar energy worldwide.

This Solar Plan has been engineered with a triple focus:

1) Identify and exploit sites owned by EDF (e.g., close to nuclear plants, unused sites or plants sites to be dismantled, floating PV on hydro power sites).
2) Availability of internal human resources and know-how holders.
3) Joint ventures with industrial and financial partners.

At the time of its release, the EDF Plan already looked back at 1.7 GW of solar installed in the world and 1 GW under construction.

A common allegation in various media (French and international) is that French authorities drive their energy strategy so to protect its nuclear electricity in metropolitan France and the linked trading/export business of nuclear energy over strong interconnections to its neighbouring countries.

In this context, ESTELA submitted in 2019 some proposals to reconsider the value of such massive investments exclusively in PV compared to a solution that would integrate in the solar Plan a part of investments in concentrated solar technology – in France or via cross-bord investments in Spain using the Cooperation mechanisms that had been promoted since 2008(!) by the EC RES Directive.

The proposals were essentially referring to the higher efficiency of (any) solar plants on sites with better DNI (such as Southern Spain) and the corresponding higher return on investment.

The proposals remained without reaction from EDF and its “voluntary initiative” towards its new Solar Plan.

Today, not especially EDF but other French actors increasingly perceive solar thermal technologies as a possible renewable heat solution if adapted to heat-consuming processes, mainly for preheating or drying operations. Indeed, about 30% of the industry's heat needs relate to temperatures below 140°C and are therefore addressable by solar thermal. Sectors that consume large volumes of hot water, such as the washing industries or the food industry, are thus privileged targets where solar can integrate reflections on the decarbonisation trajectories of the energy mix.

Meanwhile, the 2 French industry players (ENGIE, EDF EN) with the industrial potential to promote CSP projects aim essentially at either deploying French know-how for export, reducing component costs for heat installations and/or developing suitable storage facilities.

This cost stability of solar thermal applications – unlinked from gas or oil prices – appears as a real asset to reduce the dependency from fossil fuels for heat applications.

6.4.2.2 Emerging interest for CST of oil companies (post-oil era)

Most probably on a longer-term horizon, the major French oil company (TotalEnergies) is investigating possible uses of concentrated solar heat in the refinery business and for the development of new "solar fuels".

The rationale behind this interest lays in the fact that any refinery needs electrical heat-tracing to guarantee: a) the correct viscosity of the crude oil in the long-line pipes from the seaport to the storage tanks, b) the correct viscosity of the refined products in the long-line pipes from the storage tanks to the seaport, c) the continuity of production in the process piping of the hydrocracker zone, and d) for the product quality, i.e., maintaining the desired temperature of the crude oil and the refined products in the storage tanks.

6.4.2.3 Nuclear energy – a key pillar of the French electricity sector

Nuclear energy is the biggest contributor to the electricity sector and even with planned reduction of the share of nuclear from 70% to 50% by 2035, this dependency still leaves France vulnerable to a large extent. With the lack of nuclear fuel reserves in France and its overseas territories, the country is absolutely dependent on imports from outside EU, notably Kazakhstan, Uzbekistan, Namibia, and Niger. The changes in the political scene around the world following the Russian invasion to Ukraine and its impact on the energy crisis and beyond paint an unsettling picture for the future.

While a lot has been said about the high costs of CSP, the total costs of nuclear power plants over their entire lifecycle isn't clear, notably the cost of decommissioning the nuclear reactors as well as of safeguarding and maintaining of the nuclear waste, stretched over extensive period of time. As such, while the nuclear has been lobbied as a cost-efficient energy source, its true cost may be significantly higher than the one of CSP and other RES.

Realistically, nuclear energy is and will continue to be a key pillar of the French electricity sector. In this context, the target of increasing the RES share in the electricity mix comprises an open challenge for the technology or mix of technologies that will emerge as the best-fit candidates to reduce the dependency on gas and complement the generation patterns of existing and future nuclear infrastructure. From the industrial point of view, developments and advances in battery technologies not only can support the further deployment of wind and PV power, but also can serve the interests of the French automotive sector in the frame of electro-mobility. Considering that the TES capacity of CSP plants enables more economic long-duration energy storage compared to batteries as well as the supply of dispatchable power to the system, the race for the future deployment of RES in France is on for all competing technologies, including CSP.

6.4.2.4 Gas sector is part of the RES deployment via P2X or P2G

Another inhibiting factor to the deployment of CSP in France is the fact that the gas industry (not only in France, but practically in all EU member states) has a lot of lobbying efforts towards EU institutions to position the gas networks at the heart of the envisaged solution to provide sufficient storage capacity offsetting the need for storage in the power system. This strategy was also endorsed by the EC services labelled "smart sector integration" while seen as the most efficient strategy to move quicker towards decarbonisation of the European economy.

Seen from a political perspective, this makes sense due to the heavy public financing over decades of the gas infrastructures, no government is likely to leave unused or less used such infrastructures for the mere objective to increase the use of renewables or even for the sake of the environment.

But the Russian invasion of Ukraine in February 2022 has pushed European governments (except Norway) to seek for ways to reduce their respective dependency on Russian gas.

6.4.2.5 Massive need for information about dispatchability of RES

The performed review of ongoing public debates in France reveals a strong deficit of information regarding the mere existence and the potential role of dispatchable RES. Renewables are mostly assimilated to the sole wind and solar PV technologies; the clearly recognised drawback of intermittence of these two technologies is extended to all RES earmarked without distinction as intermittent leaving to other technologies only the role of "additive niches" for an optimised energy mix.

The representation of the RES sector via various platforms such as the "Syndicat des energies Nouvelles" leaves little room to other technologies than wind and PV in the context of the future scenarios for the (national) electricity. Neither did the ecology supporting party in France EELV brought the issue of dispatchable RES into the debate.

6.4.3 Integrated findings

6.4.3.1 France has a good potential for concentrated solar technologies, but is still exploring the best implementation strategy

- Due to the combination of important publicly funded research capacities, well positioned towards the governmental entities as well as at least 3 major players on global energy markets, France features an important potential for at least the *development* (if not *deployment* in France) of CST.
- While the importance of R&I on CSP has no doubt declined over recent years, France maintains besides CEA with INES as part of CNRS an important site dedicated to R&I work including capacity building objectives.
- Solar PV remains the current backbone of solar research reflecting the number of companies and the macroeconomic weight of the sector across small, mid-size and utility scale plants.

- Solar PV and wind are still promoted in France as optimal complementary technologies that fit best into the dominating nuclear strategy, while the gas network should solve the intermittence challenge inherent to PV and wind and also seen as at least a mid-term challenge for the French system. CSP is de facto discarded from any consideration for the French electricity system and no measures are taken to call for CSP projects from the industry
- France sets its focus on developing the performance of components and human resources – possibly with a view to set up in Europe new manufacturing facilities – aiming at reducing in this sector general dependency on Asian manufacturing sites that the COVID crisis has put high on the European political agenda.
- The fact that the major French players in renewables are able to respond to more favourable regulatory conditions that would provide industry with real business perspectives with any combination of technologies for the 3 sectors electricity, heat and transport, call for an integration of the solar industry with its specific business branches and opportunities and its representation towards political entities.
- This appears for the time being as not close to implementation beyond some industrial cooperation projects especially about batteries. Undocumented but real motivation to promote a wider use of batteries as flexibility provided to the electricity system because such development of the batteries technologies is expected to serve the interest of the French automotive sector.
- The competitiveness of CSP was always benchmarked under the sole criterion of LCOEs based on the argument that the "system value" of CSP (due to built-in storage) is currently not needed in France and that CSP would be detrimental to the national gas business and especially the business rentability of recently installed CCGT under the current market conditions.

6.5 Aligned conclusions and recommendations

- France is in Europe the country that binds most positive conditions for a better use of concentrated solar technologies:
  - Large promoters able to realize utility size projects both at national level as well as on world markets (EDF, ENGIE, TotalEnergies) with solid business references and international partners.
  - Large companies able to supply the full CSP value chain (Vallourec, Corning, etc.).
  - Good (even if lower than in Southern Spain) natural solar resources.
  - Good interconnections to neighbouring countries (Spain, Italy, UK, Benelux, Germany, Switzerland, Luxemburg).
  - Well-developed R&I network interconnected needs of the electricity system is discarded (the mere existence of dispatchable renewable is denied in public debates).
- The a.m. features, especially when analysed in the light of the ongoing energy crisis that is and will be further amplified by the Russian invasion in Ukraine, should lead to a clearer and **stronger reconsideration of its solar strategy** and its implementation instruments as a building block to reduce its dependency on fossil fuels.
- The strong lack of information about dispatchable renewables in France should be filled by dedicated campaign of the French authorities so to raise awareness of both decision-making authorities and the general audience on:
  - The existence (!) and the potential use of manageable/ dispatchable renewables towards decarbonisation not only of the power system but also regarding the **dependency** on fossil sources.
  - The fact that such manageable resources are **not competitors** to cheaper RES such as PV and on-shore wind, but on the contrary are providing the necessary CO_2-free backup to increase their share in the generation mix (via a *balanced* mix of intermittent and dispatchable RES).
  - The above said should also lead to **new types of dedicated procurement mechanism** (auctions and their specific design) for new capacities and their remuneration taking into consideration at least the electrical system value of such generation and possible its macroeconomic value (return on investment for the national economy).

6.6 Glossary

ADEME	French Agency for Ecological Transition (Agence de la transition écologique)
ANCRE	French National Alliance for the Coordination of Energy Research (Alliance Nationale de Coordination de la Recherche pour l'Energie)
ANDRA	French National Agency for Radioactive Waste Management
ANR	French National Research Agency (Agence nationale de la recherche)
CEA	French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique et aux énergies alternatives)
CNRS	French National Centre for Scientific Research (Centre national de la recherche scientifique)
CNTE	French National Council for Ecological Transition
CRE	Energy Regulatory Commission (Commission de Régulation de l'Énergie)
CSP	Concentrated Solar Power
CST	Concentrated Solar Technologies
EC	European Commission
ECP	Energy and Climate Planning
EERA	European Energy Research Alliance
EU	European Union
FUI	Single Inter-Ministerial Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
GWh	Gigawatt hour
H2020	Horizon 2020
HVDC	High-Voltage Direct Current
INES	National Solar Energy Institute
INSIS	Institute of Engineering and Systems Sciences
ITE	Institutes for Energy Transition
JP CSP	Joint Programme Concentrated Solar Power
ktoe	kilotonnes of oil equivalent
kW	Kilowatt
kW_{th}	Kilowatt thermal
LCOE	Levelised cost of Energy
LTECV	Law on the energy transition for green growth
MI	Mission Innovation
MTE	Ministry of Ecological Transition (Ministère de la Transition écologique)
MW	Megawatt

MW_{th}	Megawatt thermal
NECP	National Energy and Climate Plan
NICE Future	Nuclear Innovation for Clean Energy Future
OFATE	Franco-German Office for the Energy Transition
OPECST	Parliamentary Office for the Evaluation of Scientific and Technological Choices (Office parlementaire d'évaluation des choix scientifiques et technologiques)
PCI	Project of Common Interest
PIA	Investments for the Future Programmes (Programme d'investissements d'avenir)
PNGMDR	National Plan for the Management of Radioactive Materials and Waste (Plan National de Gestion des Matières et Déchets Radioactifs)
PPE	Multi-annual energy programme (programmation pluriannuelle de l'énergie)
PPE 2	Multiannual Energy Plan for the period 2019-2028
PROMES	Processes, Materials and Solar Energy
PV	Photovoltaic
R&D	Research and Development
R&I	Research and Innovation
RD&D	Research, Development and Demonstration
RES	Renewable Energy Sources
RTE	French Transmission System Operator (Réseau de Transport d'Électricité)
SET Plan	Strategic Energy Technology Plan
SMEs	Small and Medium-sized Enterprises
SNBC	National Low-Carbon Strategy (Stratégie Nationale Bas-Carbone)
SNR	National Research Strategy
SNRE	National Energy Research Strategy (Stratégie Nationale de Recherche Énergétique)
SOLSTICE	SOLAR: Sciences, Technologies, Innovations for Energy Conversion
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TRL	Technology Readiness Level
TSO	Transmission System Operator
UPVD	University of Perpignan via Domitia

6.7 Appendices

6.7.1 References

France – R&I

Agency for Ecological Transition [online]

CEA-Liten website [online]

CNRS-PROMES website [online]

National Alliance for the Coordination of Energy Research [online]

National Energy Research Strategy [online]

National Research Agency website [online]

National Solar Energy Institute website [online]

SFERA-III Concept Note for France

France – Industry

BFM Business, "Sortir du charbon et du gaz: Macron assure que la France peut y arriver "sur le quinquennat à venir"" [online]

CIA, The World Factbook, France [online]

Cigéo project [online]

Climate Transparency Report 2020 France [online]

D. Nelkin and M. Pollack, "Ideology as Strategy: The Discourse of the Anti-Nuclear Movement in France and Germany," Sci. Technol. Hum. Val. 5, 3 (1980) [online]

Directorate General of the Treasury, Decarbonising Industry in France [online]

EDF Renewables, "EDF Renewables Acquires groSolar" [online]

EDF Renewables, Solar [online]

Energy and Climate Planning [online]

Energy Regulatory Commission website [online]

ENGIE, Solar energy [online]

EU Commission, DG Energy, Unit A4 - ENERGY STATISTICS, Energy datasheets: EU countries, France [online]

Eurostat, Energy balance sheets: France, January 2022 edition [online]

Fuel cells and hydrogen joint undertaking, "Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans" [online]

General Directorate of Enterprises, Decarbonisation of industry [online]

H.Kitschelt, "Political Opportunity Structures and Political Protest: Anti-Nuclear Movements in Four Democracies," Brit. J. Polit. Sci., 16 57 (1986) [online]

IEA, Monthly OECD Electricity Statistics, Revised historical data [online]

J. Chenevey, "French Nuclear Phaseout," Physics 241, Stanford University, Winter 2017 [online]

Ministry of Ecological and Inclusive Transition, "Hydrogen deployment plan for the energy transition" [online]

Multiannual Energy Plan for the period 2019-2028 [online]

National Agency for Radioactive Waste Management website [online]

National Commission for Public Debate [online]

National Energy and Climate Plan [online]

National inventory of radioactive materials and waste [online]

National Low Carbon Strategy [online]

National plan for the management of radioactive materials and waste [online]

National strategy for the development of decarbonised and renewable hydrogen in France [online]

RTE Electricity report 2020, Wind power generation [online]

RTE website [online]

RTE, "Futurs énergétiques 2050" [online]

SolarPACES, "Morocco Pioneers PV with Thermal Storage at 800 MW Midelt CSP Project" [online]

TotalEnergies, Projects and achievements [online]

Zeeland Refinery [online]

6.7.2 Meeting guidelines

See APPENDIX.

6.7.3 Interview guidelines

See APPENDIX.

7 Chapter 7: Greece

7.1 Structure of the document

The "Integrated Country Report – Greece" aims to provide a global and structured approach of the country's profile regarding potential interest in STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2 and WP3 concerning:

- The expressed need for manageable RES energy by the country of focus and the strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.
- The construction of a defined framework for funding and its reception by relevant audiences.
- The evaluation of performance of the funding frameworks.

Section 7.2 summarises the tasks which were carried out, both on the R&I (7.2.1) and industrial (7.2.2) sides. This gives an overview of the intelligence collected and of the key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Proposition of a reshaped funding framework based on feedback from stakeholders and the IWG.
- Dissemination of information about the funding opportunities and impact evaluation.
- Meetings with relevant stakeholders, i.e., at Ministry, Transmission System Operators (TSO) and Regulatory Authority levels, as well as key players from local industries and civil society.
- Brokerage events.

A deeper analysis of the context of each country is provided in section 7.3, first for the research section (7.3.1) and then for the industry (7.3.2). Each of these sections provides a global overview of the different factors influencing the development of funding and commercialisation of STE applications. More precisely, it aims to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Greece.

Based on these observations, key findings are drawn in section 7.4, for both research and industry. They highlight encountered challenges and existing opportunities and finally draws a picture of the potential synergies between R&I and industry structures.

Last but not least, section 7.5 suggests strategic actions to continue opening doors for STE in Greece, from a research and industrial point of view. It finally offers an overarching approach to further support the development of STE in Greece, combining R&I and industry perspectives to offer thorough advice.

7.2 Summary of undertaken activities

Greece has been under the scope of analysis since February 2021. The Covid-19 global pandemic has slowed down the process. As the HORIZON-STE consortium does not include any Greek partner, ESTELA could rely on one of its members, namely the Centre for Renewable Energy Sources and Saving (CRES) in Greece, the University of Piraeus, with whom ESTELA previously worked on common projects, its participation in relevant online events, and desk research, which all combined helped to draw a first sketch of the Greek energy landscape, as well as identify relevant interlocutors at national level.

7.2.1 R&I methodology

To have a wide overview of the R&I landscape of Greece the following activities were carried out:

List of activities	Timeline
Documentation phase	Oct. 2021 - Dec. 2021
<u>Aim:</u> To collect the information available about R&I in Greece related to CST technologies (stakeholders, research centres, funding sources,..)	
Description: Since there is no Greek partner in the HORIZON-STE project, CIEMAT contacted the leading R&I entity in Greece concerning CST technologies (i.e., *the Centre for Renewable Energy Sources*, CRES) in order to get the information available about R&I stakeholders, projects, funding sources, infrastructures, and plans for the future. People from CRES were contacted, thus getting several documents with information about industries, research centres, research facilities and funding sources in Greece for R&I activities related to CST technologies and applications.	
Processing of information and writing of report	Dec. 2021 – Jan. 2022
<u>Aim:</u> To write the sections devoted to R&I in this Integrated Country Report of Greece	
Description: All the information collected during the documentation phase was analysed and processed by CIEMAT in order to get the R&I landscape of Greece for CST technologies and applications, especially those directly related to the SET Implementation Plan for CSP. The updated list of national and European R&I projects prepared by CIEMAT in 2021 within the EERA Joint Program of CSP with the inputs delivered by the Greek members of this EERA Joint Programme was also analysed to see the R&I activities currently underway in Greece and the topics covered. It was also included in this analysis the information collected by CIEMAT from several web sites and from contact people in Greece when preparing the Deliverable D1.4 ("Report on options for financing instruments and schemes") of HORIZON-STE project. The result from this analysis is given in section 7.3.1 of this document (Overview of the context in Greece: R&I Landscape"). Key findings from this information analysis and processing are given in section 7.4.1.	

7.2.2 Industry

7.2.2.1 Foreseen activities and implementation challenges

To favour a sustainable launch of STE in studied countries, ESTELA designed a general process unfolding in three steps with flexibility to adapt to specific country challenges:

PHASE 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and Greece's strategies on its procurement / possible changes in the relevant framework conditions
Encountered challenges	– To find the right interlocutor – Low answer rate to interview requests – Mixed information received from different interlocutors
Applied mitigation	– Requests to contacted persons to indicate other potential contact points and provide relevant contact information – Participation in the RENPOWER Greece Investors 2021 online conference to identify relevant stakeholders and submit questions to the Discussion Panels – Use of the virtual networking platform provided by RENPOWER Greece Investors 2021 to contact the main actors involved in the national energy policy, namely relevant Ministries, Regulatory Authority for Energy (RAE), as well as members of the National Committee for the Energy and Climate Plan – General translation of official documents from Greek to English – Confrontation of different sources with the official source
PHASE 2	
BROKERAGE EVENT	
General aim	Assessment and presentation of potential solutions using CSP/STE
Encountered challenges	– Outbreak of covid-19 global pandemic – RES auctions dominated by PV and wind projects
Applied mitigation	– On-line meetings with national stakeholders
PHASE 3	
JOINT NATIONAL EVENT	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	– Outbreak of covid-19 global pandemic – Not enough data collected yet
Applied mitigation	– Awaiting the end of the pandemic to evaluate the possibilities

7.2.2.2 Carried out activities – Industry perspective in Greece

LIST OF ACTIVITIES		TIMELINE
BACKGROUND RESEARCH		Phase 1 Feb.-Aug. 2021
Aim: To collect relevant information to better understand the energy landscape in Greece, the potential challenges for the development of STE and the needs of the country		
Description		
Desk research:	Collection of information based on available information on official websites (e.g.: Hellenic Ministry of Environment and Energy (YPEN), Independent Power Transmission Operator (ADMIE), RAE, Renewable Energy Sources Operator & Guarantees of Origin (DAPEEP), European Commission, International Energy Agency…), academic studies or reports by consultancies	
Stakeholder mapping:	Analysis of the specific relevant departments and actors for each identified target group Exchanges with CRES and University of Piraeus on relevant contacts and existing knowledge of the local situation	
PRELIMINARY TALKS		Phase 1 Feb.-Aug. 2021
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable RES, the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions		
Description Ideally, this phase aims to establish a first physical contact with the three key stakeholders in Greece regarding energy policy, namely the TSO, the Ministry and the REA. However, due to the Covid-19 pandemic situation, these meetings had to be organised via teleconference.		
ADMIE	Interview with the Director of Strategy & System Planning Department and the Head of system studies and development branch	
RAE:	Interview with representatives of RAE	
YPEN	Not possible to schedule an interview with representatives of YPEN	
BROKERAGE EVENT		Phase 2 Feb.-Aug. 2021
Aim: To have a broad overview of STE perspectives in Greece through existing and potential solutions using STE, from both the R&I and industry sides.		
Description A series of online meetings with national stakeholders were held as a mitigation measure due to the COVID-19 pandemic restrictions.		
NATIONAL EVENT		Phase 3 Not applicable
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the support of Greek STE industries involved in foreign STE projects and concentrated solar thermal technologies for industrial heat. To focus on possible synergies and macro-economic value. Description Not applicable.		

7.3 Overview of the context in Greece

7.3.1 R&I landscape

This section presents the main outcome of the background research and the analysis of the information collected from CRES and other sources contacted by CIEMAT for this purpose. It is divided into the financial framework, the ongoing R&I activities of Greek research entities and the strategies defined in Greece that have an impact into the focus of research and funding.

7.3.1.1 Funding opportunities for R&I activities in Greece related to CST technologies

There are no *a priori* special national funds dedicated to CSP/STE in Greece. Funding to developmental STE-related projects comes from the same pool as all other R&I areas. This is rather usual in most of the countries analysed.

Current R&I funds are part of the National Strategic Reference Framework (NSRF) 2014-2020 (extended until 2022). The total budget for all R&I activities for the period in question is about 956 M€, while the total budget for NSRF is about 25,565 M€. The NSRF budget is a mix of EU and national funds at a ratio of approximately 80/20. Despite the high rate of participation of EU funds, the whole package categorises (with a few exceptions) as "*funded by national sources*".

The main actions of the R&I funds package, in which also STE-relevant activities are in-principle included but not in the form of designed STE-dedicated actions, are briefly described in the following sections. National R&I activities on CST in Greece are funded by such multiyear NSRF programmes, which are also the main developmental tools for a variety of other than R&I sectors. R&I funds are managed by the General Secretariat for Research & Technology[161] (GSRT) of the Ministry of Development and Investments.

Concerning periodicity of the Calls, the funding sources in Greece are relatively unstable with respect to the periodicity of the Calls of most actions. Typically, in the beginning of each NSRF period, there is a delay of 1-2 up to several years before most of the actions are initiated. In the last NSRF, after the delayed activation for its R&I part, a relatively good periodicity was observed, but in any case, the situation in Greece in terms of this aspect is quite far compared to the exemplary stability of H2020, Horizon Europe or other past EC R&I Framework Programmes.

Some funding programs in Greece support national stakeholders when participating in international projects. This is the case for the ERANET and the Transnational (bilateral) R&I Collaboration funds, which both have a total budget of 75M€ for the current period.

7.3.1.2 Existing R&I activities and infrastructures

Compared with other European countries, Greece has a high solar radiation level with high sunshine duration and therefore has a strong advantage for efficient solar applications, especially in the field of solar thermal energy. This is why Greek research and

[161] *See www.gsrt.gr*

technological development institutions are involved in activities related to CST technologies since long time ago, at both national and international level. However, most of the solar thermal R&I activities are related to low-temperature (T<100°C) solar applications and Greece is recognized as one of the leading countries worldwide in the use of solar systems for hot water, presenting one of the highest solar collector area installed per capita rates. The main solar thermal product in Greece was and still is the thermosiphon water heater, composed of flat plate collector(s) and storage tank. Furthermore, the building sector is the most energy intensive sector of the Greek economy by consuming more than 66% of the produced final electricity. It is therefore logical that every effort to reinforce the use of solar thermal systems in buildings is of particular interest in Greece. So, the number of projects and the budget devoted to CST technologies in Greece is not high. The main research areas in the CST field in Greece are:

- Application of CST technologies to industrial heat processes.
- Advanced thermal energy storage concept.
- Solar fuels production.
- Solar cooling.
- Solar plants with supercritical carbon dioxide (sCO_2).

The main R&I stakeholders in Greece are:

- CRES[162].
- Centre for Research and Technology Hellas (CERTH)[163].
- Aerosol and Particle Technology Laboratory (APTL/CERTH).
- Solar & other Energy Systems Laboratory - NCSR "Demokritos"[164].
- Patras University - Applied physics division[165].
- Technical University of Crete[166].
- The National Technical University of Athens, School of Mechanical Engineering [167].

Although the know-how and experience of these R&I stakeholders in the low-temperature solar applications are the core of their activities in solar energy, they are getting more and more involved in CST-related activities (see Table 1). Most of these R&I entities have significant computational and simulation capacities that can be used for CST systems.

Additionally, the APTL/CERTH has a 66 kW solar simulator (Figure 46), which consists of eleven 6 kW xenon short arc lamps close-coupled to ellipsoidal aluminium mirrors, that are individually controlled and are able to concentrate the produced radiation on a single

[162] *See http://www.cres.gr*

[163] *See https://www.certh.gr*

[164] *See http://www.solar.demokritos.gr*

[165] *See https://www.upatras.gr*

[166] *See https://www.tuc.gr*

[167] *See http://www.mech.ntua.gr*

spot, with the possibility of operating on two separate spots, where high temperatures can be achieved. This facility, which is unique in Greece and among a handful worldwide, was developed for the study of candidate materials and process conditions related to solar-thermochemical cycles for water (H_2O) and carbon dioxide (CO_2) splitting for solar fuel generation. This solar simulator is able to achieve temperatures higher than 2000 °C in a focal spot of ~60mm diameter and concentrations over 4000 suns. Applications that make use of this facility are:

- Innovative research for solar chemistry, solar fuels.
- Pre-Screening instead of expensive solar field tests.
- Accelerated aging of materials, material properties, thermal shocks.
- Life cycles of materials.
- Uniform large-area radiation of porous materials.
- Prescreening of Modules for volumetric Receivers.

Figure 46: 66 kW solar simulator at APTL/CERTH

CRES has a facility for solar cooling systems in Pikermi with a 35 kW absorption chiller and 150 m^2 collector area. Although this facility has been traditionally used for low temperature system, it could be used for medium temperature solar cooling systems.

A solar furnace is being implemented at the facilities of the APTL/CERTH in Thessaloniki and it is expected that it will be in operation in the next years, when the required funding is available.

The key data of national and European R&I projects with Greek partners projects are shown in Table 36.

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Greek Industrial Partners	Greek R&I Partners
EU	SOLAR based sCO2 Operating Low-cost plants	SOLARSCO2OL	RINA CONSULTING SPA	2020-2024	Mas AE Proigmenes Technologies Energeias & Ischyos	CERTH
EU	HYDROSOL-beyond Thermochemical HYDROgen production in a SOLar structured reactor:facing the challenges and beyond	HYDROSOL-beyond	CERTH	2019-2022	---	CERTH
EU	Solar Calcium-looping integration for Thermo-Chemical Energy Storage	SOCRATCES	UNIVERSIDAD DE SEVILLA	2018 - 2021	---	CERTH, Aristotle University of Thessaloniki
EU	Renewable Power Generation by Solar Particle Receiver Driven Sulphur Storage Cycle	PEGASUS	DLR	2016-2021	---	APTL/CERTH

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Greek Industrial Partners	Greek R&I Partners
N	Use of Concentrated Solar Radiation in the Cement Industry: Design of a suitable, integrated and low carbon footprint process for limestone calcination	SOLCEMENT	CERTH	2018-2021	MIRTEC S.A., TITAN Cement S.A.	APTL/CERTH, National Center for Research in Natural Sciences (NCSR) "Demokritos"
N	Development of a Mobile system for processing and energy exploitation of recovered industrial materials, Bioliquids, biological resources, waste/rejections utilizing Solar	MoBiSol	CERTH	2018-2021	PAKO S.A., ELDIA S.A., CAMPUS S.A., RENOVOIL, SPANOS Technologies	APTL/CERTH

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Greek Industrial Partners	Greek R&I Partners
	thermochemical technology					
EU	Integrating National Research Agendas on Solar Heat for Industrial Processes	INSHIP	Fraunhofer (DE)	2017-2020	---	CRES
EU	Application of Solar Thermal Energy to Processes	ASTEP	UNED (Spain)	2020-2024	Galaktokomika Mandrekas Anonymi Etaireia, Production Trade and Support of Machinable Products of Software and Informatics - Relational Technology AE	CRES

Table 36: R&I Projects with involvement of Greece partners relevant to the SET IP (only those projects ending in 2020 or later have been included)

7.3.2 Overview of the context for industry

The desk research and first preliminary interviews helped ESTELA refine its understanding of the energy context in Greece. The following subsections were enriched thanks to ESTELA's own desk research and inputs from the ADMIE and the RAE in Greece, which both provided the consortium with thorough information and useful insights in the context of energy policy in Greece.

7.3.2.1 Energy policies and the place of STE in the Greek landscape

7.3.2.1.1 Current energy mix in Greece

Greece is highly dependent on oil and petroleum products, which represent more than half of the total final energy consumption in 2019, as shown in Figure 47[168]. A closer look at the data presented in Table 37 reveals that the transport sector and households account for almost two-thirds of final energy consumption in Greece, followed by the industry sector. Figure 48 details the breakdown of energy sources used by sector.

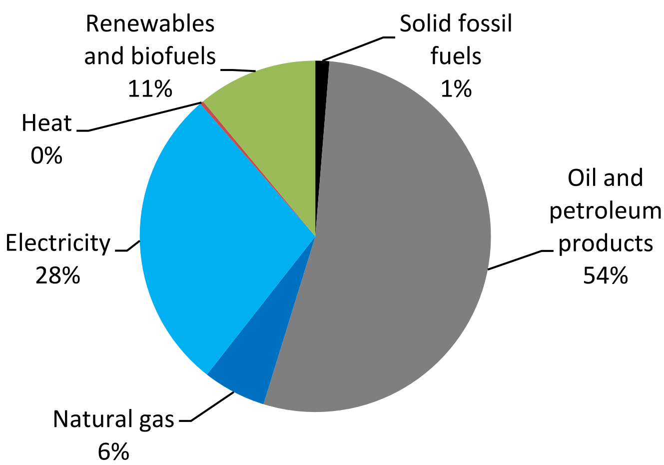

Figure 47: Percentage breakdown of final energy consumption by fuel in Greece, 2019 (Source: YPEN)

[168] *Source: Hellenic Ministry of Environment and Energy, Statistical data 2019*

Sector	Final energy consumption	
	ktoe	Percentage share
Industry	2587,6	16,8%
Transport	6046,0	39,3%
Commercial & public services	2135,5	13,9%
Households	4114,0	26,7%
Agriculture & forestry	277,5	1,8%
Fishing	14,3	0,1%
Other	227,1	1,5%
Total	15.401,9	100,0%

Table 37: Breakdown of final energy consumption by sector in Greece, 2019 (Source: YPEN)

In those three main energy consuming sectors (Figure 50), fossil fuels represent more than two-thirds of total consumption. More specifically, oil and petroleum products are dominantly consumed in the transport sector, while fossil fuels account for 37.5% of the energy consumption in households. Importantly, almost one-fourth of energy consumption in households stems from renewables and biofuels. In the industry sector, the consumption of fossil fuels is more than half of the energy consumed, with electricity having a large share of around 41%.

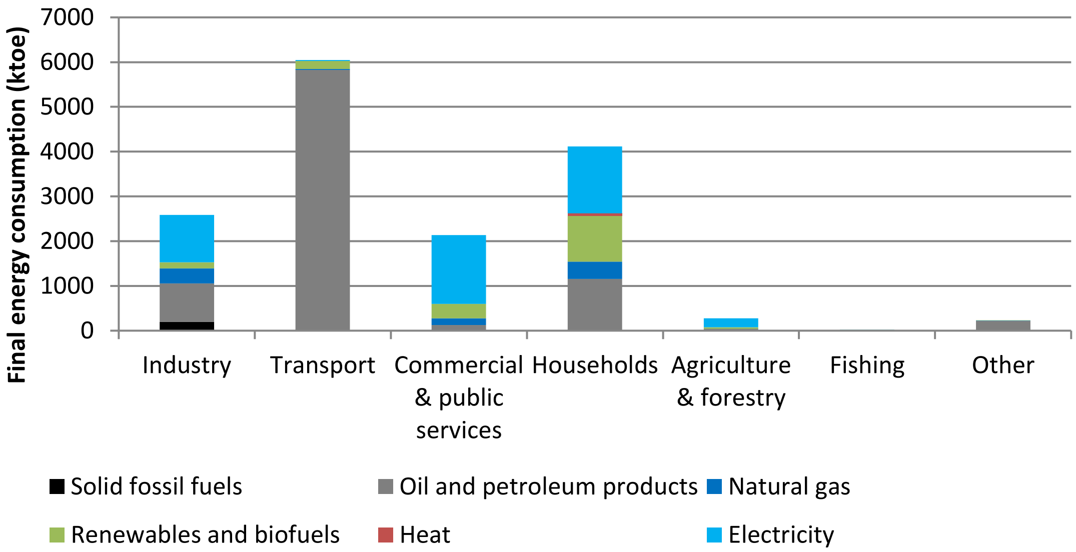

Figure 48: Breakdown of energy sources in final consumption by sector in Greece, 2019 (source: YPEN)

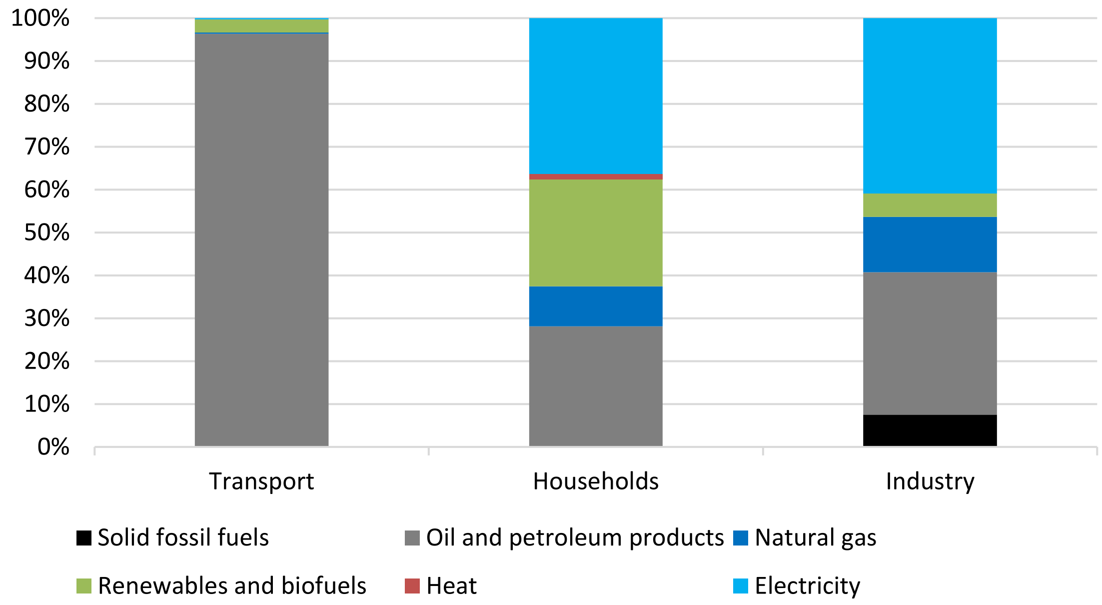

Figure 50: Share of energy sources in three main consuming sectors

As shown in Figure 49, in 2019, fossil fuels represented 65% of electricity generation in Greece, while renewables accounted for the other 35%[169]. The highest share of RES is represented by wind, which equals to 15% of total generation and 42% of total RES generation in Greece.

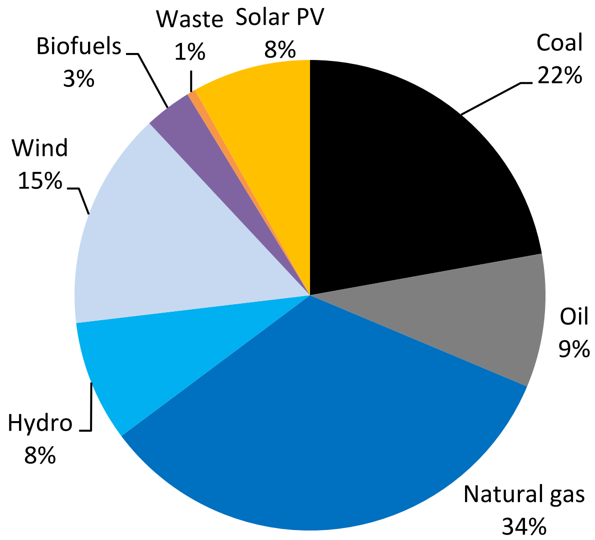

Figure 49: Electricity generation by source in Greece, 2019 (source: IEA)

[169] *Source: IEA Electricity Information 2020*

In 2019, the total installed capacity for electricity production in Greece was 20,478.1 MW, with the percentage breakdown by source shown in Figure 51[170]. Combustible fuels account for more than half of the installed electricity production capacity in 2019, however lignite-fired power plants in Greece are gradually phased-out from the power system, until the full decommissioning of all existing lignite-based units by 2023, according to the decisions of the Greek Government.

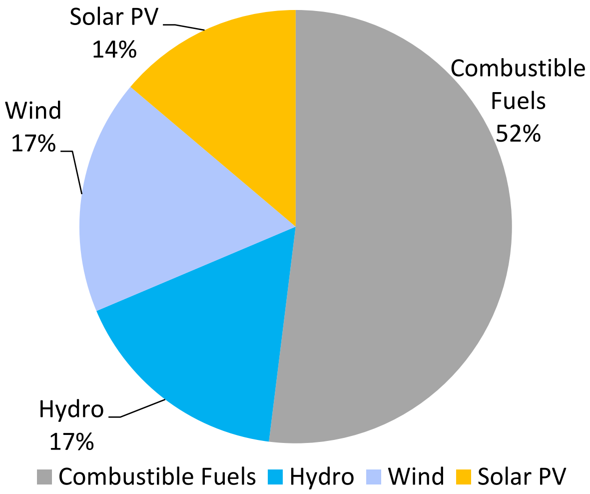

Figure 51: Percentage breakdown of installed capacity for electricity production by source in Greece, 2019 (source: EU Commission, DG Energy)

The positive impact from the gradual decommissioning of existing lignite-fired power plants is reflected on the evolution of the energy balance from 2018 to 2020, as shown in Figure 52[171]. More specifically, electricity generation from RES (excluding hydro) increased from 21% in 2018 to 29% in 2020, while lignite-based generation dropped from 29% to 11% for the same period. It is noted however that electricity imports from neighbouring countries and generation from natural gas have also increased.

[170] *Source: EU Commission, DG Energy, Unit A4, ENERGY STATISTICS, Energy datasheets: EU countries*

[171] *Source: Regulatory Authority for Energy [Greece], Statistics*

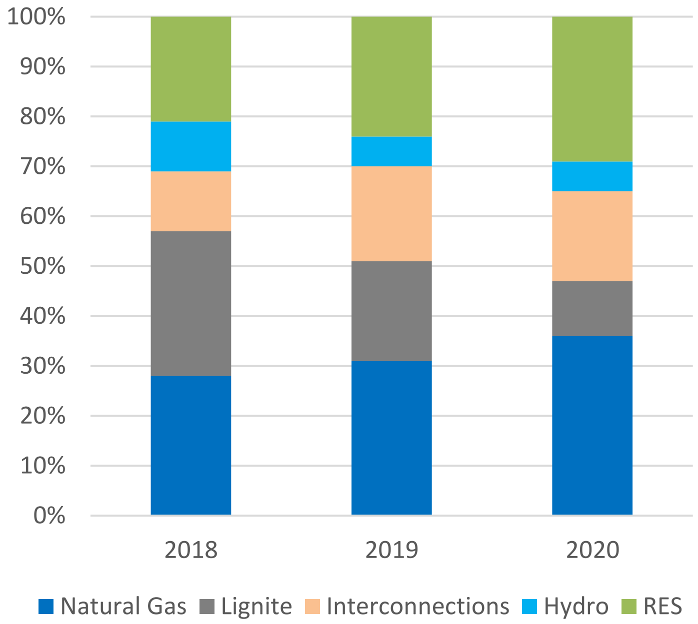

Figure 52: Energy balance of Greece from 2018 to 2020 (sources: YPEN, RAE)

As of January 2021, the installed RES capacity in Greece was 7441 MW, with the distribution of each technology as shown in Figure 53[172]. Wind represents more than half of installed RES capacity, followed by large PV plants and small-scale rooftop PV systems, which combined account for 42% of RES capacity.

[172] *Source: Renewable Energy Sources Operator & Guarantees of Origin, DAPEEP's Newsletter, January 2021*

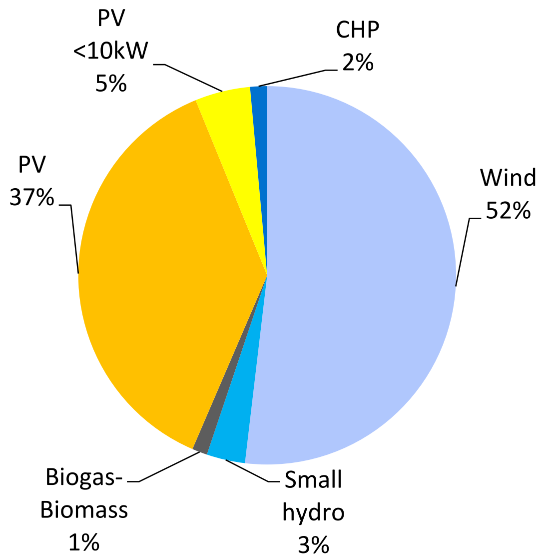

Figure 53: Percentage breakdown of installed RES capacity for electricity production by source in Greece, 2020 (source: DAPEEP)

Figure 54 presents the monthly breakdown of electricity production by source from January 2019 to March 2021 in Greece, clearly showing the progressively increasing role of RES in electricity generation, the decreasing dependence on coal-fired power plants, as well as the higher dependence on natural gas power plants.

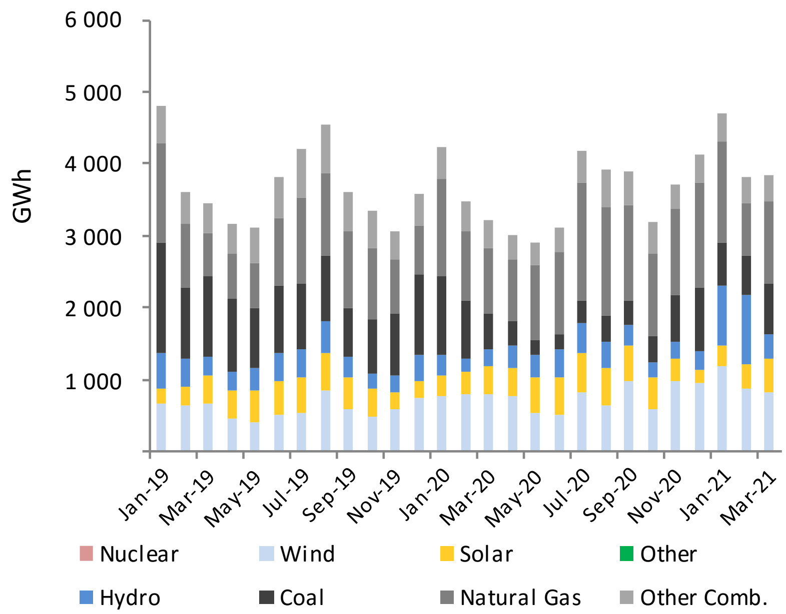

Figure 54: Monthly electricity production in Greece (source: IEA)

The Greek electricity transmission system includes interconnections with Albania, Northern Macedonia, Bulgaria, Turkey and Italy. The interconnections balance in 2020[173] (Table 38) shows that Greece was a net importer of electricity, with significantly higher quantities of imported electricity compared to those exported.

Interconnections balance in 2020	
Electricity imports [GWh]	9,828.6
Electricity exports [GWh]	967.0
Net imports [GWh]	8,861.6

Table 38: Electricity imports and exports in Greece, 2020 (source: IEA)

Finally, Greece recognises the key role of cross-border interconnections in the integration of variable RES in the electricity system, and therefore is in discussions with all neighbouring countries to increase the capacity of interconnections in order to reach, and more importantly to exceed, the EU targets for 2030 in the National Energy and Climate Plan (NECP). In addition to this, the plan of actions for adding flexibility to the system, and thus effectively deal with the increasing share of variable RES, also foresees the addition of new flexible gas-fired units along with large-scale battery storage.

7.3.2.1.2 The Greek NECP and the potential for STE

Greece has submitted an ambitious the NECP[174], with a greenhouse gas emission reduction target of more than 42% compared to emissions in 1990 and more than 56% compared to emissions in 2005. More specifically, Greece set the following targets for 2030:

- At least 35% of RES in its gross final energy consumption.
- At least 60% of RES in the gross final electricity consumption.
- At least 40% of RES in the heating and cooling needs.
- At least 14% of RES in the transport sector.

To reach these targets, Greece foresees a significant increase of its RES installed capacity by 2030, planning to almost double its wind power installed capacity and more than double the PV installed capacity in the decade 2020-2030. Table 39 provides a detailed overview of the capacity targets for 2030, as mentioned in the NECP.

Power generation, installed capacity [GW]	2020	2022	2025	2027	2030
Biomass & biogas	0.1	0.1	0.1	0.2	0.3
Hydro (incl. mixed pumping)	3.4	3.7	3.8	3.9	3.9
Wind farms	3.6	4.2	5.2	6.0	7.0
Photovoltaics	3.0	3.9	5.3	6.3	7.7

[173] *Source: IEA, Statistics Report - Monthly OECD Electricity Statistics (data up to March 2021)*

[174] *Source: HELLENIC REPUBLIC - Ministry of the Environment and Energy, National Energy and Climate Plan, see: https://ec.europa.eu/energy/sites/ener/files/el_final_necp_main_en.pdf*

Power generation, installed capacity [GW]	2020	2022	2025	2027	2030
Solar thermal	0.0	0.0	0.1	0.1	0.1
Geothermal	0.0	0.0	0.0	0.0	0.1
Total	10.1	11.9	14.6	16.4	19.0

Table 39: Evolution of installed RES capacity in power generation (Source: NECP)

The target share of 35% from RES in the gross final energy consumption by 2030 is a sufficiently ambitious target according to the Commission's assessment of the NECP[175], as compared to the EU's 2030 target for renewable energy of at least 32%. The 18% share of energy from renewable sources in gross final consumption of energy in 2018 was also the target for the year 2020. Towards the 2030 target, the NECP provides a trajectory of interim reference points, which are all above the levels required by Article 4 of the Governance Regulation. Specifically, the interim shares of energy from renewable sources in gross final energy consumption provided in the NECP are 23.4% in 2022, 27.1% in 2025, and 29.6% in 2027, representing 31.8%, 53.6% and 68.5% of progress required between 2020 and 2030 respectively.

Focusing on electricity generation, Greece has set a target of at least 61% in renewable electricity by 2030, with wind and solar PV as the main contributing technologies. The data presented in the previous section indicate that Greece is on track with the projection of 29.2% electricity generation from RES in 2020 in the NECP. Importantly, the NECP foresees the installation of 0.1 GW of CSP capacity by 2030.

Measures supporting the energy security include diversification of sources from third countries through new electricity and natural gas infrastructure, such as interconnection of Greece-Bulgaria, Inter-Adriatic pipelines and East-Med pipelines. Increase of domestic energy production by exploiting domestic hydrocarbon resources and developing new RES plants, coupled with electricity storage systems, is also considered in the NECP. Natural gas is viewed as the transitional fuel due to the lignite decommissioning, with the future objective to feed biomethane or hydrogen into the natural gas network for final uses. Greece plans to make significant investments in storage of electricity and natural gas, while the use of liquefied natural gas from different supply routes is also examined to improve the security of energy supply. In the same direction, Greece plans to interconnect the islands with mainland (where possible) by 2029 and set up infrastructure projects, e.g., autonomous, innovative hybrid renewable power generation systems.

With respect to the internal energy market, the NECP of Greece includes not only a new electricity market design following the EU's Target Model (already in operation), but also coupling of the day-ahead and intraday markets with its neighbours.

The NECP provides a high-level overview of energy subsidies and expresses the intention to reduce or phase out existing subsidies. In this direction, the Commission's assessment underlined the lack of a detailed list of energy subsidies, in particular for fossil fuels, as well as of specific actions and plans to phase out these subsidies.

[175] *Source: Commission Staff Working Document, Assessment of the final national energy and climate plan of Greece, SWD(2020) 907 final, October 2020*

Greece estimates the total accumulated investment needs for the period 2020 - 2030 to implement the NECP at around EUR 43.8 billion, split over the various sectors, without specifying however the contribution from public and private funding per policy area.

7.3.2.1.3 CSP projects in Greece

Currently, there are no CSP plants commissioned in Greece, however two CSP projects shall proceed to construction. The fully-licenced (installation licence) MINOS Project will install a 52 MW CSP central receiver tower with a 5-hour molten salt heat storage system in “Atherinolakkos”, Municipality of Sitia, Crete. The CSP plant will cover an area of 1.6 km^2, while the annual electricity production is estimated at 110 GWh[176]. The EPC contract was signed in November 2019, signifying the first CSP project in Greece and the first export of Chinese CSP technology to Europe[177]. The project is expected to create more than 500 jobs in the local area during the construction period, as well as 50 long-term jobs during the 25-year operation period[178]. Moreover, the HYPERION 1 project, having been granted a production licence, will construct a 70 MW parabolic trough CSP plant with approximately 8 hours storage[179] in the island of Crete (location “Fournia” in the Municipality of Sitia) with an estimated annual electricity production of 168 GWh. Similarly, the project is expected to create 650 jobs during the construction period and 70 jobs during the period of commercial operation[180].

A third CSP project is currently on hold, namely the MAXIMUS project[181] located in the northwest of Greece in the region of Florina, which has been selected for funding together with the Minos project in the first round of EU's NER300 programme. It is a large-scale Stirling dish power plant with a total installed capacity of 75.3 MWe, consisting of 25160 Stirling dish units, each with 3 kW rated power output.

According to the RAE’s public geo map[182], there are also other 43 small CSP projects in Greece with capacity of 10.5 MW or less, however it is rather unknown how many and

[176] *See: https://ypodomes.com/minos-to-emvlimatiko-iliothermiko-project-tis-kritis-me-ellino-kineziki-sfragida/*

[177] *See http://www.nurenergie.com/index.php/news/129/66/Minos-named-Deal-of-the-Year-by-Chinese-Business-Law-Journal*

[178] *See https://helioscsp.com/greece-minos-50mw-tower-concentrated-solar-power-project-epc-contract-awarded/*

[179] *See https://energypress.gr/news/hyperion-megalytero-adeiodotimeno-iliothermiko-sti-siteia-tis-kritis-ishyos-70-mw-iliaki*

[180] *See https://www.enterprisegreece.gov.gr/en/invest-in-greece/strategic-investments/investment-projects/confirmed-projects/construction-of-concentrated-solar-power-plant-of-70-mw-capacity-in-fournia-municipality-entity-itanos-municipality-of-sitia-regional-entity-of-lassithi-region-of-crete*

[181] *Drosou, V., Christodoulaki, R., Kyriaki, E. and Papadopoulos, A.M., 2020. CONCENTRATING SOLAR THERMAL SYSTEMS IN GREECE: CURRENT STATUS AND FUTURE POTENTIAL, see http://proceedings.ises.org/paper/eurosun2020/eurosun2020-0088-Drosou.pdf*

[182] *See https://geo.rae.gr/*

which ones will proceed to an installation licence, and finally to construction, since their production licence dates back to 2011 and 2012.

7.3.2.2 Hydrogen strategy in Greece

Since early stage of research, Greece has considered hydrogen as a future energy solution and is continuedly active in the research of hydrogen production from RES. As noted in the NECP, the country's approach to develop hydrogen as low-carbon solution is based on the following pillars:

- Hydrogen production from renewable electricity.
- Hydrogen use to decarbonise the transport sector (mainly shipping).
- Long term hydrogen storage for power generation.
- Use of existing gas infrastructure for hydrogen transport.
- Stimulate hydrogen related R&I[183].

At the beginning of 2022, the Greek government drafted the country's hydrogen strategy plan, which is expected to be put on public consultation mid-2022. The strategy covers a period from 2022 to 2030 and beyond that is divided in three phases:

- The first phase concerns the period from 2022 till 2027, with uncertainty and high costs with no hydrogen infrastructure. During this period, the Greek government will support and invest in new initiatives.
- The second phase concerns the period from 2027 till 2030, with pilot projects being deployed. The role of the government remains a key with emphasis on incentives (tax and aid). Private initiatives are welcomed.
- The third phase concerns the period beyond 2030, with government aid and incentives declining and hydrogen market strengthening with private initiatives and related investments.

The national hydrogen strategy includes more than 30 measures related to the production and distribution of hydrogen, the use of hydrogen and biogas, the institutional framework (yet to be developed), research and innovation[184].

Alongside the drafting of national hydrogen strategy, research institutions have joined forces with gas, oil and construction companies and in May 2022 submitted the national proposal "White Dragon", a response for a call for expression of interest for Hydrogen Important Projects of Common European Interest. "White Dragon" presents the development of an innovative integrated green hydrogen project in Greece which covers

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[183] *See https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20Greece%20%28ID%209473091%29.pdf*

[184] *See https://www-insider-gr.translate.goog/sustainability/221216/sdoykoy-ethniki-stratigiki-30-metron-gia-ydrogono-simantikes-oi-kratikes?_x_tr_sl=el&_x_tr_tl=en&_x_tr_hl=en-US&_x_tr_pto=wapp*

the entire hydrogen value chain, with an investment that exceeds the amount of 8 billion €.

The goal of the project is to gradually replace the lignite power plants of West Macedonia, transition to clean energy and the de-carbonisation of the country's energy mix. The project will use large-scale renewable electricity for the production of green hydrogen by electrolysis in Western Macedonia. Hydrogen will then be stored directly (short-term hydrogen storage) and indirectly (streaming through natural gas pipeline) and, subsequently, through high temperature fuel cells will provide the country's power grid with electricity as a fixed base load co-generation unit of green energy and heat. The generated heat, as a by-product of green electricity production, could initially have a complementary use to the district remote heating networks of West Macedonia, as well as in other applications that require heat and / or cooling in the future[185].

Research shows that Greece has high potential for hydrogen. The country has ammonia industry and refineries, both of which currently use fossil-derived hydrogen. Although the capacity is low, these facilities provide already existing infrastructure for the deployment of renewable or low carbon hydrogen. Furthermore, Greece has an important scientific potential to lead projects focusing on using hydrogen as a fuel in the shipping sector, in targeted areas/applications (e.g., barges at terminals or hydrogen-electric ferries). With the above mentioned developments, as well as numerous other projects currently in the making, Greece is more than equipped for the transition to the green hydrogen.

7.3.2.3 Energy regulation in Greece

The RAE in Greece was established in 1999 as an independent regulatory authority with the main responsibility to supervise all sectors of the domestic energy market, counselling the competent bodies of the Greek State and taking measures to achieve the goal of liberalisation of the electricity and gas markets. Since then, the role of RAE has been upgraded to include responsibilities not only on monitoring and control of the energy market, i.e., electricity production from conventional fuels, RES and natural gas, but also responsibilities in relation to the petroleum market, as well as licencing process of RES plants and the process of evaluating applications for production licences, and last, crucial responsibilities for regulating the electricity and gas markets.

In 2020, RAE completed the elaboration of the regulatory framework for the structural reform of the wholesale electricity market according to the EU Target Model. Towards the convergence with the European standards, the new electricity markets were launched on November 1, 2020, while the coupling with the Italian and Bulgarian markets took place on December 15, 2020 and May 11, 2021 respectively. Currently, the legislative framework for licencing storage facilities in the Greek electricity market is under development and expected to be finalised in 2021. The corresponding regulatory framework for market participation is also under development and expected to be completed in 2022, along with the technical decisions for connection issues and provision of services. Importantly, the pre-announcement of the auction framework for new storage facilities is expected by the end of 2021.

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[185] *See https://www.depa.gr/white-dragon-proposal-submitted-for-ipcei-hydrogen-important-projects-of-common-european-interest/?lang=en*

With respect to the RES auctions in Greece, RAE implements different types of auctions, either technology-specific or technology-neutral, for small or large wind and PV projects. The last RES auction in Greece was held on May 2021 as technology-neutral for small wind and PV projects, with the latter being the sole winners. There is an additional wind and PV generation capacity of 350 MW to be auctioned in 2021 and a total renewable generation capacity of 2.1 GW until 2024. In the frame of the RENPOWER Greece Investors 2021 online conference attended by ESTELA, the YPEN reported that a prolongation of the existing auctions support scheme for RES has been secured until 2025, and despite the fact that auctions are currently for wind and PV projects, other technologies will be included if they show significant growth.

PVs have, on average, a lower levelised cost of electricity (and a simpler licencing process) compared to wind projects, thus the former dominate the latter in joint auction schemes, notwithstanding that both are the two cheapest electricity production technologies, even when compared to lignite, gas and other RES technologies that are currently excluded from the auctions in Greece. This has opened a national discussion on performing future joint RES auctions with a quota of 30% per technology. This approach, in turn, could potentially create problems in the design of the auction parameters, e.g. on the rule for determining the common starting price of the auction. At this point, it is important to note that the competent institutions, in particular RAE and the ADMIE, should always have the necessary flexibility to regulate and design the basic parameters of RES auctions, such as technology mix and starting auction prices of technologies, for the benefit of the consumer.

ESTELA contacted RAE to inquire about its views on the latest orientations and objectives of the national energy policy strategy as well as on the potential of CSP in Greece. RAE emphasised that Greece is strongly committed on increasing RES penetration by revising its NECP towards more ambitious targets. Since 2017, the deployment of RES in Greece has been through competing processes, with great interest from investors, particularly in PVs due to the very low levelised cost of electricity and the automated licencing process allowing for very fast applications. The approved applications for new RES capacity of 100 GW are indicative of the high competition, resulting in significant drop of the auction prices (e.g., at 33 €/MWh as of May 2021). Currently, the interest in CSP from investors is not high, given the attractiveness of PVs in terms of cost and the preference of big investors in Greece on wind power, especially in islands where the wind energy potential is very high.

Greece however experienced high power system balancing costs during the winter of 2021, bringing in the foreground the need for electricity storage. Licences of 10 GW storage capacity, including pumped hydro and other technologies with various storage durations, were issued in a period of 1 year (as of end of August 2021). These applications are for 3-4 hours of storage, while applications of 6 hours are expected in 2023, with batteries and pumped hydro currently seen as the main options to cover the storage needs of the Greek power system.

Moreover, RAE confirmed that curtailments of variable RES is an existing issue in the islands, e.g., close to 10% in Crete. This explains to a large extent, on the one hand, the high interest in terms of applications for hybrid systems in the islands (PVs with battery storage being the most common technology), and on the other hand, the Greek TSO's network development plan to interconnect almost all islands (i.e., Cyclades, Crete, Dodecanese and

North Aegean islands) within a decade, which is considered to be the biggest investment from TSOs in Europe with 4.5 billion €.

With respect to the auction design of new RES capacity in Greece, RAE commented that the target of 1 GW of new RES capacity per year will be possibly increased in the updated NECP, supplemented by storage technologies. The new RES capacity is expected to be equally distributed between PV and wind projects, while a part of the latter will be covered by off-shore wind. To that end, other regulatory schemes will be discussed in the future to accommodate the off-shore wind technology, such as the Offshore Transmission Owner from Ofgem in the UK. RAE further clarified that the Ministry of Energy is responsible for the design parameters of the auctions, while applying a minimum quota of 30% per technology is a State Aid issue that has to be approved by the EC Directorate General for Competition.

RAE also confirmed that hydrogen has a role to play in the long term energy planning of Greece, while the roadmap of the National Hydrogen Strategy will be shortly put on public consultation. Interestingly, the main energy companies in Greece have already formed a consortium for a more than 5 billion € construction project of a green hydrogen plant in the frame of the Greek power system delignification. Last, RAE recognised that sector integration is an open challenge for Greece as the gas network is not fully developed yet.

7.3.2.4 Energy transmission system in Greece: the role of ADMIE

The ADMIE has the dual responsibility of: (i) the operation, control, maintenance and development of the Hellenic Electricity Transmission System, (ii) the operation of the electricity market for transactions outside the Day Ahead Scheduling.

Recognising the key role that interconnections play in the integration of variable RES into the Greek electricity system, the aim of ADMIE is to reach and even exceed the target of 15% by 2030 set in the NECP for interconnections with neighbouring countries. In this direction, there is a planned expansion of the connection capacity with Bulgaria, i.e., a 400 KV overhead line to increase the connection capacity to 800 MW for exports and 1350 MW for imports of electricity, which is to be constructed and commissioned by 2022. Moreover, there is a Memorandum of Understanding (MoU) with TERNA (Italian TSO) to construct a second interconnection between Greece and Italy in 2022, with plans to make a relevant announcement by the end of 2021. The discussions with Albania and North Macedonia are still in a preliminary stage. Importantly, there is also a Joint Taskforce working on a trilateral interconnection between Greece, Turkey and Bulgaria as the East Balkan corridor, however no political decision has been made yet for its implementation. Another key infrastructure project is the Eurasia interconnector between Israel, Cyprus and Greece, which is to be commissioned in 2023. In the Eurasia interconnector, the link between Cyprus and Greece will be via the island of Crete.

ADMIE considers that the integration of variable RES in the Greek power system is already a challenge that will be more pronounced in the next five years, when the currently installed RES capacity (7 GW) will have increased by at least 30% or more, as the NECP foresees the installation of 1 GW new RES capacity per year. To effectively address the potential grid stability issues, the action plan with respect to adding flexibility to the system focuses not only to the increase of the interconnections capacity, but also to the incorporation of new natural gas fired power plants and the addition of battery storage to the Greek power system. In this direction, the energy policy agenda in Greece is currently focused on the batteries, storage projects and the new regulatory framework enabling battery storage in combination with RES (storage behind the meter). Many storage projects are designed (preliminary phase) and in the next 5 years it is expected to have grid-scale battery storage stations. There are 3 existing pumped storage facilities in Greece, while a storage project of 700 MW in Amfilochia is mature to be implemented. At this point, it is noted that the initial idea for a molten-salt storage facility was finally abandoned.

According to ADMIE, the need for the interconnections of Crete with the mainland of Greece is to reduce the energy dependence of the island on oil-based power plants. The Crete-Peloponnese interconnection is completed[186], while the interconnection with Attica is estimated to be completed in 2023[187]. The aim is to create a green island based only on RES, however there is no updated information on the progress of the CSP projects MINOS or HYPERION 1 in Crete.

7.3.2.5 Involvement of authorities, stakeholders, and society in goals and challenges of national energy planning

The integration of renewable energy is challenging, as it involves the cooperation of political and decision-making authorities with other stakeholders, research centres, universities, local community, civil society and NGOs. Widespread integration of RES in Greece is essential to achieve the EU's 2030 decarbonisation target, although the availability of suitable sites for the installation is partially obstructed by society's opposition. The civil society perspective is the key to understand the non-financial barriers that hinder the access and penetration of renewable energy, and as such, their direct involvement in the debates about the deployment of RES projects in Greece is crucial.

The assessment of the various levels of acceptability of selected RES technologies (wind, hydro, and photovoltaic) in the areas of interest in Greece is often conducted through questionnaires involving civil society and local residents of the targeted areas, from which more public information on the exploitation of RES has often been found.

As an example of the involvement of the local community in the debates, it's worth noting the resistance that has been put to the HYPERION 1 CSP plant. The reaction from local community and civil society was negative and, as a result, the project was suspended. After this stalemate, the project was updated with the new Environmental Assessment and received the final approval from the regional authorities.

Over the last years several initiatives have been organised with a target to identify and draft measures and policies that could contribute to reaching energy, ecological and social goals. Further aim was to make a valuable contribution to the economic development of Greece and to protect consumers by embracing a sustainable national energy distribution model. Some examples include:

[186] *See https://www.admie.gr/en/nea/deltia-typoy/crete-peloponnese-record-breaking-interconnection-completed*

[187] *See https://www.admie.gr/en/erga/erga-diasyndeseis/diasyndesi-tis-kritis-me-tin-attiki*

- On 2 April 2018 a workshop "Goals and Challenges of National Energy Planning" was held with institutional and market stakeholders, as well as NGOs attending. More than 110 participants attended the workshop.
- On 18 June 2018 debates at regional and municipal level were held regarding the local dimensions of the energy and climate plan. More than 85 representatives attended the debate, discussing the questions regarding their view about the obstacles and challenges facing implementation of the plan.
- On 29 November 2018 a workshop that included industry, universities and public bodies was organised with an aim to prepare and submit a proposal within the framework of the consultation on national priorities and policies for a decade in the areas of research, innovation, and competitiveness in the field of energy. More than 170 participants attended the workshop.

More examples are to be mentioned, highlighting the importance of social debate during the political decision making, especially regarding energy transition. One of the latest examples is a public consultation, launched on 22 November 2021, following the UN Climate Change Conference (COP26) and its first climate law to address the global environmental crisis by decarbonising the economy and accelerating the deployment of RES capacities. The positive result of this consultation is the assurance for the protection of the environment, notably flora and fauna.

7.3.2.6 International cooperation in the energy sector

Greece is in a pivotal position on the periphery of Europe, facing east and south, with strong links to Asian and African countries. Its position, combined with its strategic alliances with Cyprus, Israel, and Egypt, gives the opportunity to play a key role in several regional energy markets, such as the Balkans or the immensely important south-eastern Mediterranean.

During the drafting of the NECP, specific actions that can contribute to achieving the energy, environmental, and existing regional cooperation on energy and climate issues were taken into account in order to assess possible synergies.

The aim of the cooperation between Greece-Cyprus-Jordan, on the basis of the MoU signed on 16 January 2018, is the exchange of information and know-how, policy development on renewable energy, energy efficiency, innovation and pilot projects in buildings, with a focus on the integration of near-zero energy buildings and the integration of RES.

The purpose of the MoU between Greece, Cyprus, Israel and Italy signed in Nicosia on 5 December 2017 was to ensure a direct and long-term export route to Greece, Italy and other European markets. This confirms the parties' intent to cooperate in the development and implementation of the EastMed Pipeline project as a viable and strategic choice for natural gas-producing countries. In the same direction, the focus of the joint Greece-Cyprus-Israel statement within the framework of the fourth summit held in Nicosia on 8 May 2018 was on the accomplishment of intergovernmental cooperation for the East Med pipeline.

The objectives of the Greece-Cyprus-Egypt Joint Declaration on the occasion of the 6th summit held in Elounda, Crete, on 10 October 2018 were the promotion of RES, diversification of energy sources, extraction and exploitation of hydrocarbons, and security of supply. Egypt could become a supplier of electric power, produced mainly by solar technologies, and Greece will become a distribution station to Europe. This interconnection strengthens the cooperation and energy security with Europe and will be a means of transferring significant amounts of electricity to and from the Eastern Mediterranean[188].

According to the NECP, the collaboration between Greece and Germany extends beyond intensifying policy and measures for renewables and energy efficiency under the TARES (2013-)/SRSS project. Specifically, it includes promoting innovative technologies, exchange of knowledge and experience, as well as R&I activities for innovative and pilot projects.

With respect to collaboration beyond the EU borders, it is worth noting how China and Greece have long shared the same vision on the development of the energy sector. In this regard, there are substantial collaboration opportunities between the two countries to support the transformation of the energy sector, pointing to RES technologies, and particularly to solar and wind power, as an area where China and Greece could join their efforts. Examples of such collaboration include the following:

- In November 2019, one of the world's largest energy companies, China Energy Investment signed an investment partnership with the Greek Copelouzos Group covering four wind energy projects located in Thrace, Trikorfo, Mani and Crete[189]; as part of the agreement, the Chinese group will enter into the equity of a significant pipeline of wind farms built by Copelouzos Group[190].
- China Energy Europe Renewable Energy, a subsidiary of China Energy Corporation, operates four wind farms in Thrace, generating nearly 180 million kWh of electricity annually, helping to reduce carbon dioxide emissions by 160,000 tonnes and save 55,000 tonnes of coal[191].

Last, transnational partnerships for Research and Technology (R&T) projects in the energy sector are also promoted via the GSRT in Greece. Joint calls for R&T projects launched by GSRT involve the submission of proposals for the implementation of bilateral R&T cooperation projects in the energy sector, while the proposals submitted are compatible with the strategic areas of Research, Technological Development and Innovation and the thematic priorities set out in the National Strategy for Smart Specialisation (RIS3) 2014-2020. Such calls for proposals refer to the implementation of bilateral R&T cooperation projects between Greece and China, Germany or Israel, among others.

[188] *See https://www.lemondedelenergie.com/energie-accord-egypte-grece-chypre/2021/10/19/*

[189] *See https://energypress.eu/china-energy-enters-four-copelouzos-group-wind-energy-projects/*

[190] *See https://balkangreenenergynews.com/china-energy-gains-renewable-foothold-in-greece-eyes-balkan-expansion/*

[191] *See http://french.china.org.cn/foreign/txt/2019-11/18/content_75420295.htm*

7.4 Key findings

7.4.1 R&I

7.4.1.1 Limited scope of activities and facilities for CST technologies in Greece

Although Greece is a country with a good level of direct solar radiation, their activities in the field of CST technologies are focussed on industrial process heat applications and solar fuels, mainly. Most of the solar thermal R&I activities are related to low-temperature (T<100°C) solar applications and Greece is recognized as one of the leading countries worldwide in the use of solar systems for hot water, presenting one of the highest solar collector area installed per capita rates.

The Greek R&I entities with more activities in these topics are the Aerosol and Particles Technologies Laboratory (APTL) of CERTH and the CRES. The number of experimental facilities and laboratories for CST technologies is very small, because the most outstanding facility is the 66 kWe solar simulator operated by APTL/CERT in Thessaloniki.

7.4.2 Industry

7.4.2.1 A window of opportunity for CSP in the longer term

Based on the available data from RAE, the rather small number of projects with or having applied for a production licence since years, without showing significant further progress since then, suggests that CSP does not seem currently to be of significant favour and interest. Presently there are no specific plans regarding potential future auctions for CSP and the implementation policy considering the targets of the NECP plan.

However, as pointed out by RAE, in the context of the new energy market regime ("target model"), almost all RES technologies should be able to "guarantee" their daily production schedule, subsequently they become at least balancing responsible parties. This can be seen as a promising window of opportunity for CSP in Greece in the longer term, given that it is among the few RES that combine technological maturity with dispatchability and capability to guarantee the daily production (due to the use of TES).

7.4.3 Integrated findings

7.4.3.1 CSP as facilitator of RES investments in Greece

It is a commonly acknowledged truism that the dominant integration of a single variable RES technology in a power system is far from the optimal solution. For instance, a high penetration of PVs in Greece can create "energy gaps" under non-favourable meteorological conditions or during night-time, and even face problems in meeting the demand of energy-intensive consumers, such as the industrial ones. Importantly, a high penetration of variable RES increases the level of curtailments in the power system. The relevant Inductive Planning study performed by Protermosolar for the case of Portugal not only confirms that adding new CSP capacity allows for more variable RES integration and contributes to further decarbonisation of the system, but also highlights the flaws in the procurement methods for new renewables, as well as the fact that curtailments are more than an operational issue for TSOs, hiding a number of market- and investment-related risks and threats. In this context, ensuring the stability of the electricity grid and, at the same time, effectively achieving the climate and energy targets set in the NECP requires a combination of RES technologies that complement each other, based on their particular technical characteristics and individual profile of electricity production. Such a combination of RES technologies can lead to the economically optimal development and operation of the power system, ensure optimal utilisation of the grid and energy sources, and protect all investors, even the investors of PVs, from increasing the possibility of zero price occurrences in the market.

7.5 Aligned conclusions and recommendations

- Considering the excellent solar resources of the country, Greece should not discard CSP as an option to reduce its dependence on imported energy, given that about 40% of its annual energy needs are covered with Russian gas.
- In this context, Greece could also count on further EU support for coordinated planning and financing of cross-border and national infrastructure as well as energy projects and reforms, especially via the RRF which is at the heart of the REPowerEU Plan.
- The expansion of the energy system based on a least-cost strategy appears questionable, hiding a number of market dysfunctions, which however can be overcome by the improvements that CSP can bring to the electricity system, e.g., reduction of the level of intermittent RES curtailments.

7.6 Glossary

ADMIE	Independent Power Transmission Operator
APTL/CERTH	Aerosol and Particle Technology Laboratory
CERTH	Centre for Research and Technology Hellas
CRES	Centre for Renewable Energy Sources and Saving
CSP	Concentrated Solar Power
CST	Concentrated Solar Thermal
DAPEEP	Renewable Energy Sources Operator & Guarantees of Origin
EC	European Commission
EU	European Union
GSRT	General Secretariat for Research & Technology
GWh	Giga Watt hour
H2020	Horizon 2020
IWG	Implementation Working Group
ktoe	Kilo Tonne Oil Equivalent
kWh	Kilo Watt hour
MoU	Memorandum of Understanding
MS	Member States (EU)
MW	Mega Watt
MWh	Mega Watt hour
NECP	National Energy and Climate plan
NSRF	National Strategic Reference Framework
PV	Photovoltaic
R&I	Research and Innovation
R&T	Research and Technology
RAE	Regulatory Authority for Energy
RES	Renewable Energy Sources
SET-Plan	Strategic Energy Technology Plan
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TSO	Transmission System Operator
YPEN	Hellenic Ministry of Environment and Energy

7.7 Appendices

7.7.1 References

Greece – R&I

Centre for Renewable Energy Sources and Saving website [online]

Centre for Research & Technology Hellas website [online]

General Secretariat of Research and Innovation website [online]

National Technical University of Athens, School of Mechanical Engineering website [online]

Solar & Other Energy System Laboratory website [online]

Technical University of Crete website [online]

University of Patras website [online]

Greece – Industry

Assessment of the final national energy and climate plan of Greece [online]

Balkan Green Energy News, "China Energy gains renewable foothold in Greece, eyes Balkan expansion" [online]

EnergyPress, "China Energy in 4 Copelouzos Group wind energy projects" [online]

EnergyPress, "Hyperion 70 MW project in Crete" [online]

Enterprise Greece, Invest & Trade, "Construction of Concentrated Solar Power Plant in Fournia" [online]

French China Organisation, "La Chine et la Grèce renforcent leur coopération énergétique" [online]

Fuel Cells and Hydrogen Joint Undertaking, "Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans" [online]

Greek NECP [online]

HelioCSP, "Greece MINOS 50 MW Tower Concentrated Solar Power Project EPC contract awarded" [online]

Independent Power Transmission Operator, "Crete-Peloponnese: The record-breaking interconnection is completed" [online]

Independent Power Transmission Operator, "Interconnection of Crete with Attica" [online]

Insider Greece, "30 measures in the national strategy for hydrogen" [online]

International Solar Energy Society, "Concentrating Solar Thermal Systems in Greece: Current Status and Future Potential" [online]

Le Monde de L'Énergie, Rejoignez la Communaute, "Energie: signature d'un accord entre l'Egypte, la Grèce et Chypre" [online]

NUR Energie press release "Minos named "Deal of the Year" by Chinese Business Law Journal" [online]

Public Gas Corporation of Greece S.A., ""White Dragon" proposal submitted for IPCEI Hydrogen Important Projects of Common European Interest" [online]

RAE GeoPortal website [online]

7.7.2 Meeting guidelines

See APPENDIX.

7.7.3 Interview guidelines

See APPENDIX.

8 Chapter 8: Denmark

8.1 Structure of the document

The "Country Report – Denmark" aims to provide a global and structured approach regarding potential interest in STE (as well as broader use of CST), from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP2 concerning:

- The expressed need for manageable RES energy by each country of focus and their respective strategies on its procurement.
- The possible changes in the framework conditions.
- The interest for and reception of potential solutions using STE.

Part summarises the tasks which were carried out, describing first the initial plan (8.2.1) and then the actual work carried out (8.2.2). This gives an overview of the intelligence collected and of the final key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

- Meeting with relevant stakeholders, i.a. at Ministry, TSO and Regulatory Authority levels, as well as key players from local industries and civil society.
- Brokerage event and joint industry-R&I national events.

A deeper analysis of the context of the country is provided in section 8.3, first from the political point of view (8.3.1) followed by a focus on the regulatory (8.3.2) and transmission (8.3.3) aspects. The overview of the current industrial landscape (8.3.4) closes this part. More precisely, this part aims at large to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Denmark.

However, these observations could only be drawn from HORIZON-STE's own desk research, since no contact could be established by the time of writing this report. Despite ESTELA's attempts to retrieve information from the Danish company Aalborg CSP or from a Danish representative in the SET-Plan or IWG Steering Group, no substantial interest was shown from their sides. The consortium is therefore unable to show any key finding or recommendations, even though heat applications appear as promising in the country.

8.2 Summary of undertaken activities

Denmark has been under the scope of analysis since January 2020. As the HORIZON-STE consortium does not include any Danish partner, ESTELA first turned to Aalborg CSP, a Danish company with a CSP branch. However, as exchanges were not fruitful, ESTELA turned to representatives to the SET-Plan and to the IWG Steering Group, both contacts provided by the European Commission. No answer has been received so far, despite reminders.

This has hindered the foreseen process of analysis and reduced HORIZON-STE's activity for Denmark to only background research. While Denmark seemed promising, with already good examples of heat applications, the absence of contact with major stakeholders prevented the project from performing further analysis. Hence, given that the consortium was not able to get relevant information from direct official sources to understand the country's needs, making concrete and suitable propositions for the further deployment our off taking of CST in the country became impossible.

8.2.1 Foreseen activities and implementation challenges

To favour a sustainable launch of STE in studied countries, ESTELA designed a general process unfolding in three steps with flexibility to adapt to specific country challenges:

PHASE 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and Denmark's strategies on its RES procurement strategy/ possible changes in the relevant framework conditions
Encountered challenges	– No answer from contacted stakeholders, except for an industrial one but with heavier focus on the Spanish market, not on Denmark – No apparent interest in sharing contacts without a tangible benefit in return – Important information and documentation available only in Danish
Applied mitigation	– Sending reminders – Looking for alternative contacts – General translation of official documents from Danish to English
PHASE 2	
BROKERAGE EVENT	
General aim	Assessment and presentation of potential solutions using STE/CST
Encountered challenges	– Not possible to plan, as no contact with relevant stakeholders was achieved
Applied mitigation	– Looking for alternative contacts
PHASE 3	
JOINT NATIONAL EVENT	
General aim	Focus on possible synergies and macro-economic value

Encountered challenges	– Not possible to plan, as no contact with relevant stakeholders was achieved
Applied mitigation	– Looking for alternative contacts

8.2.2 Carried out activities – Industry perspective in Denmark

LIST OF ACTIVITIES	TIMELINE
BACKGROUND RESEARCH	Phase 1 Jan. – May 2020
Aim: To collect relevant information to better understand the energy landscape in Denmark, the potential challenges for the development of STE and the needs of the country	
Description Desk research: Collect of information based on available information on official websites (e.g.: Ministry of Climate, Energy and Utilities [EFKM], Forsyningstilsynet [Regulator], Energinet [TSO], European Commission, Danish Energy Agency …), academic studies or reports by consultancies Stakeholder mapping: - Analysis of the specific relevant departments and actors for each identified target group - Exchanges with the European Commission for direct contacts – Attempts to exchange with Aalborg CSP, a representative to the SET-Plan and a representative to the IWG Steering Group	
PRELIMINARY TALKS	Phase 1 Feb. – May 2020
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable renewable energy sources (RES), the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions	
Description Despite emails and reminders sent to the representatives of Denmark to the SET-Plan and the IWG Steering Group, no answer was received. It was later found out that the representative to the SET-Plan quit around March 2020 and no replacement is known at the moment.	
PHONE INTERVIEWS	Phase 1 Feb. – June 2020
Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of Denmark's energy strategy and potential need for manageable RES	
Description ESTELA contacted several persons from Aalborg CSP, as the Danish company is very well advanced in CSP and heat applications in the country. After several emails with the CEO and the Vice-President of Aalborg CSP, they oriented the consortium towards the Spanish Sales Manager. Even though the person took time to talk to ESTELA, he could not provide us with information significantly valuable from the Danish market, since he was in charge of the Spanish branch. The only additional cooperation offered by the company, regarding digging the Danish market and interesting stakeholders, would have required a financial contribution. Aalborg: Interview with Aalborg's Sales Manager in Spain	
BROKERAGE EVENT	Phase 2 Not applicable.
Aim: To have a broad overview of STE perspectives in Denmark through existing and potential solutions using STE, from both the R&I and industry sides.	

LIST OF ACTIVITIES	TIMELINE
Description Not applicable.	
NATIONAL EVENT	Phase 3 Not applicable.
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the development of STE in Denmark. To focus on possible synergies and macro-economic value. Description Not applicable.	

8.3 Overview of the context in Denmark

The following sections are based only on the desk research performed by ESTELA, to refine its understanding of the energy context in Denmark. None of the contacted Danish stakeholders expressed the will to answer ESTELA's questions regarding Danish energy needs and potential for concentrated solar thermal technologies in the country.

8.3.1 Energy policies and the place of STE in the landscape

8.3.1.1 Current energy mix in Denmark

Denmark is one of the most advanced European countries in terms of penetration of renewable energies in its energy mix. With currently 33% of renewables in its gross final energy consumption[192], the country is already ahead of its initial target of 30% for 2030[193]. The three main sectors for energy consumption in 2018 were transports (29%), households (29%), agriculture and industry (21%).

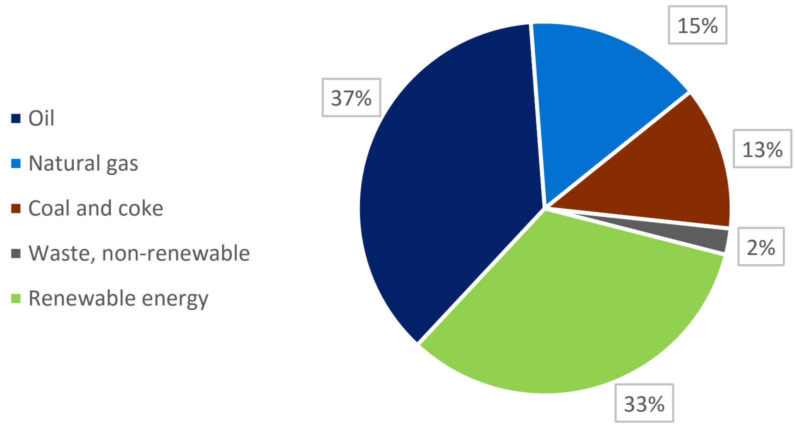

Figure 55: Danish global energy mix (2018)

Regarding electricity, as can be seen in Figure 56, renewables represent 69% of the generation, with wind accounting for 66% of the total generation by renewables. This means that wind represents around 46% of the total electricity generation in Denmark. A

[192] *Source:* Danish Energy Agency, Annual and Monthly Statistics, Figures 2018, DEA website

[193] *Source: Eurostat, Renewable energy in the EU in 2018, News release, 23 January 2020 [online]*

more detailed vision of the composition of the Danish electricity system can be seen in Figure 56 below and in Table 40[194].

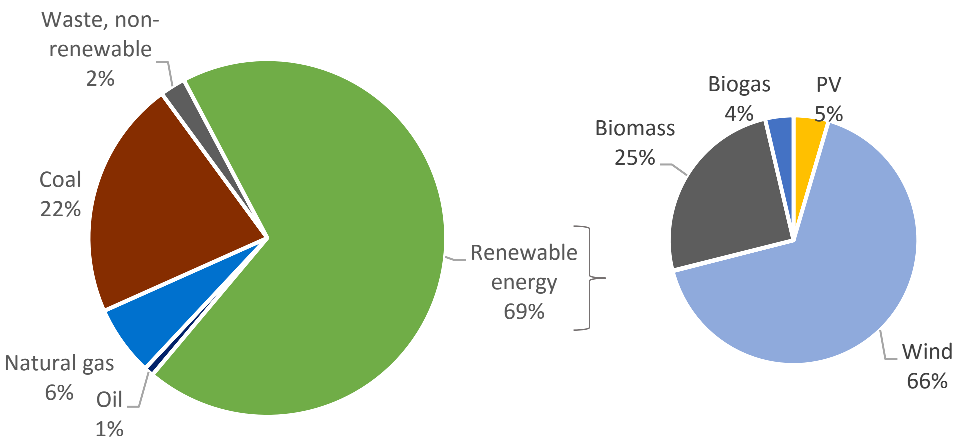

Figure 56: Electricity production

Denmark's electricity system in 2018		
Total installed capacity		15,073MW
Amongst which:	Wind	6,121MW
	Solar	998MW
	Hydro	9MW
	CHP[195]	4,586MW
Total net electricity production		ca. 29,320.83GWh
Final electricity consumption		ca. 31,084.44GWh
Total import		15,634GWh
Total export		10,409GWh

Table 40: Danish electricity system (2018)

One characteristic of Denmark lies in its focus on developing combined heat and power (CHP), for both electricity and district heating production. It represents 71% in thermal electricity production and 66% in district heating production, as can be seen in Figure 57[196]. More than half of of district heating production relies on renewables (58%), of which 72% only produced by biomass (wood and straw). This means that in total, 42% of district heating is generated by biomass in Denmark[197].

What is interesting with district heating, is that storage is a very important feature to ensure the flexibility of the system. Heat can thereby be produced in excess during the day, stored and be dispatched at night when needed. That is why a potential for CST exists in Denmark. It could also be beneficial to deepen the penetration of RES in the energy

[194] *Source:* Danish Energy Agency, Annual and Monthly Statistics, Figures 2018, DEA website

[195] *Combined Heat and Power*

[196] *Source: Danish Energy Agency, Energy in Denmark 2018, March 2020 [online]*

[197] *Source: ibid.*

mix, in particular of PV, which still represents a very low amount of installed capacity. CHP systems can also relay electricity production when not enough is available, thanks to this storage capacity.

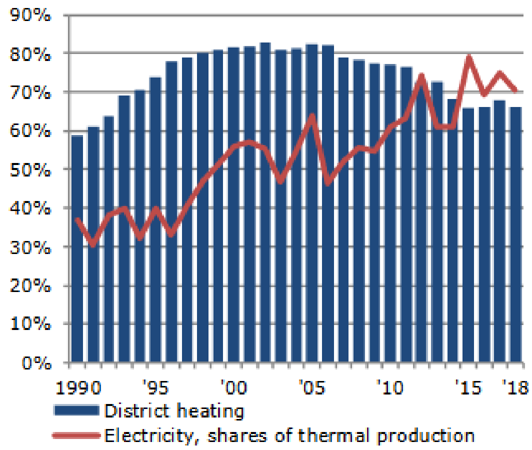

Figure 57: CHP shares of electricity and district heat production

8.3.1.2 The Danish NECP

In its NECP, Denmark is even more ambitious than the EU general binding targets are. Denmark is part of the group of countries which exceeded their 2020 targets in terms of renewables, and should also meet its targets for GHG emissions and energy savings[198], which included:

- A total renewables share of 30%.
- A 20% co2 reduction in non-EST greenhouse gas emissions.

For 2030, Denmark aims to reach a share of 55% of renewables in its energy system, phase out of coal in electricity production, and ensure that at least 90% of district heating production is based on other energy sources than coal, oil or gas[199].

Wind power will play a key role in increasing the share of renewables in the system, in particular offshore wind. Already 400MW of offshore wind are operational since 2013, an additional 1,350MW was tendered in 2019 (under three auctions of respectively 400MW, 600MW and 350MW)[200]. Three new offshore wind tenders are planned between 2020 and 2030, representing a total of minimum 2,400MW.

[198] *Source: Danish Ministry of Energy, Utilities and Climate, Denmark: energy and climate pioneer Status of the green transition, April 2018, EFKM website*

[199] *Danish NECP, p.29*

[200] *Ibid., p. 36*

No objectives or targets for individual technologies have been set up by the government. The current subsidy system relies on multi-technology tenders for wind and PV, with the new ones planned for 2020-2024.

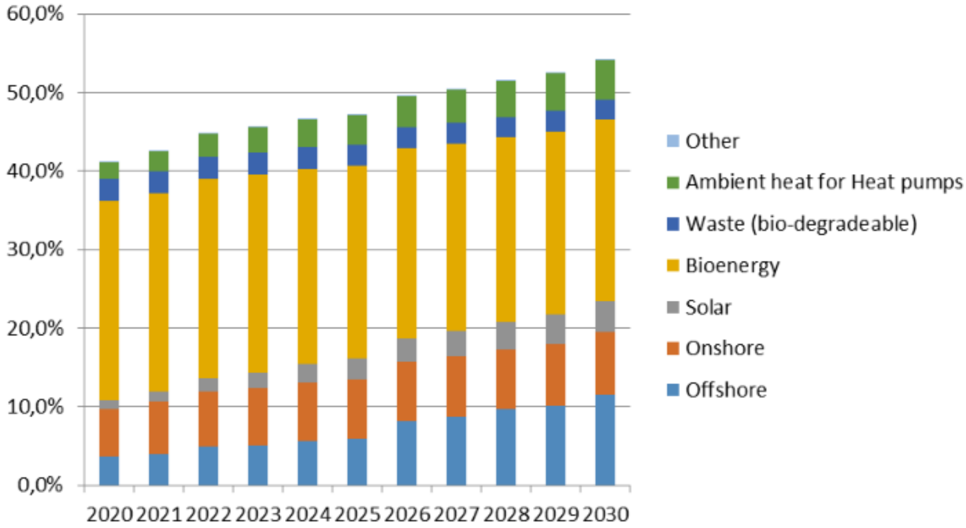

Figure 59: Estimated trajectory for the overall share of renewable energy, by technology

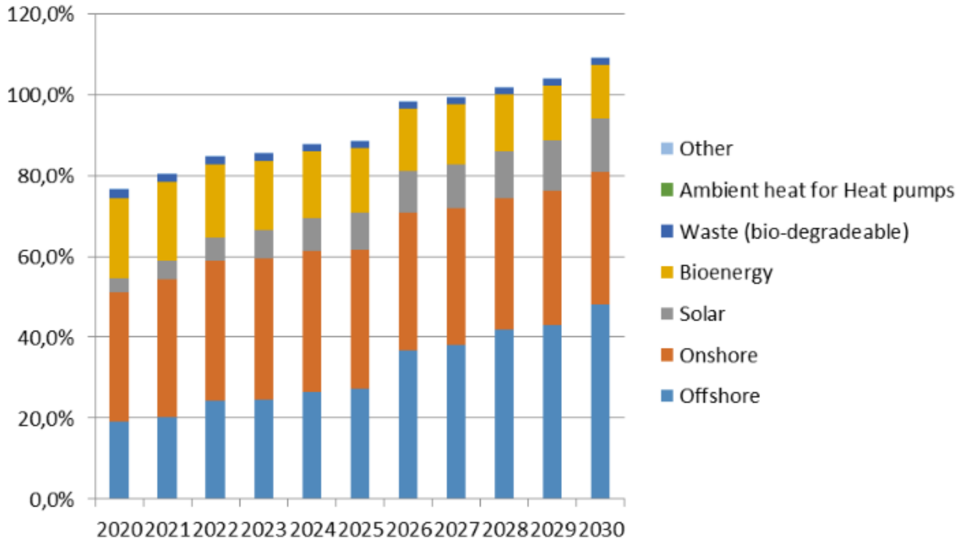

Figure 58: Estimated trajectory for renewables in electricity

By 2030, the estimated installed capacity of renewables for electricity production will be:

- 10,147MW of wind.
- 7,842MW of PV.
- 1,710MW of biomass.
- 7MW of hydro.

This large increase of variable renewables in terms of electric capacity highlights the importance of finding accurate storage solutions to secure a reliable and flexible system. In these terms, the clear mention of the NECP that "it is an objective to support structures that favour demand response and energy storage markets"[201] could open interesting opportunities for CST technologies in Denmark, even though the district heating sector seems to be the favoured option.

According to the NECP, "Solutions regarding energy storage will also be promoted concretely through an Energy storage fund of 128 million DKK. In December 2019 money was granted to two Power-to-X-projects. The projects will establish big scale production and storage of green hydrogen. Both projects have an ambition to demonstrate production and consumption of green hydrogen on near market-based conditions."[202] The focus on hydrogen also represents an opportunity window for the development of concentrated solar thermal technologies in the country, or its import.

In terms of GHG emissions, Denmark aims to reduce them by 70% by 2030. Aware of how ambitious this target is, the government stated within the NECP that this challenge will require "currently unknown methods"[203].

8.3.1.3 DECO19[204]: A scenario for 2030

DECO19 is a baseline scenario projection towards 2030 by the Danish Energy Agency, based on existing measures. One upcoming measure, if carried as planned, could be beneficial for the CST technology sector, namely the technology-neutral tendering rounds (2018-2024). The tendering rounds can be interesting if storage appears as a distinctive feature in the tendering process.

Denmark also plans to reduce the electricity tax for some businesses to the EU-minimum level and has set up a special task force to analyse possibilities to optimise the tariffs and tax regime to favour demand side management and flexible energy consumption. It would be interesting to have more information from EFKM regarding this task force. Incentives for renewables, manageability and flexibility might open the door for storage and heating processes offered by CST technologies.

In terms of energy consumption, the DECO19 foresees an annual increase of 0.4% of the final energy consumption, while the gross energy consumption would remain around the levels of 2017. Denmark's main source of increased consumption would come from data centres, according to the projection, which also opens the question of waste heat recuperation. This would represent an annual increase of 3% of electricity consumption.

Electricity generation will mainly be provided by wind power, and the share of RES in electricity consumption should exceed 100% from 2028 on, to reach 109% in 2030, as can be seen on Figure 60. Denmark is thereby expected to become a large net exporter of electricity. If no new measures are implemented, net exports of electricity could constitute 12% of electricity production in 2030.

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[201] *Ibid., p. 64*

[202] *Ibid. p. 112*

[203] *Ibid., p. 29*

[204] *All references in this section, except when explicitly mentioned, are taken from the Danish Energy Agency, Denmark's Energy and Climate Outlook 2019, October 2019, DEA website [online]*

However, achieving these shares highly depends on the phase out of large-scale coal-fired and small-scale gas-fired CHP. Natural gas consumption for production of electricity and district heating will be divided by almost four by 2030, while coal consumption will be divided by 12. All in all, the total final consumption of fossil fuels by 2030 for electricity and district heating production should decrease by 85% compared to 2017.

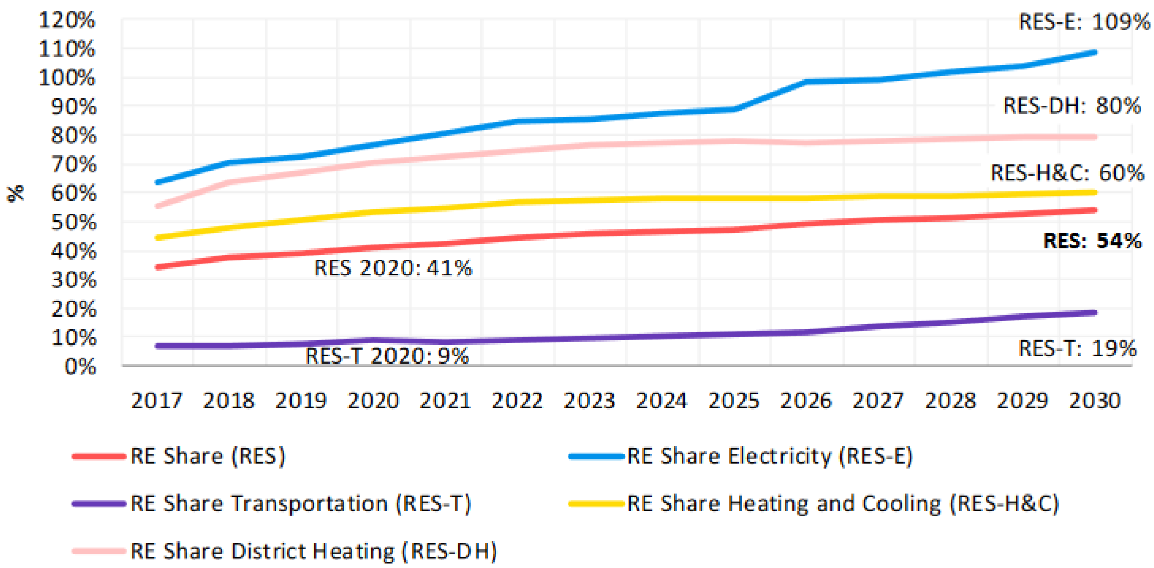


Figure 60: Renewables shares 2017-2030

Industry and services are expected to still be fossil fuel consumers by 2030, as shows Figure 61, while renewables would just represent 13% of the final energy consumption of these sectors in 2030. More than ¾ of this is expected to be used for medium- and high-temperature process heat in 2030.

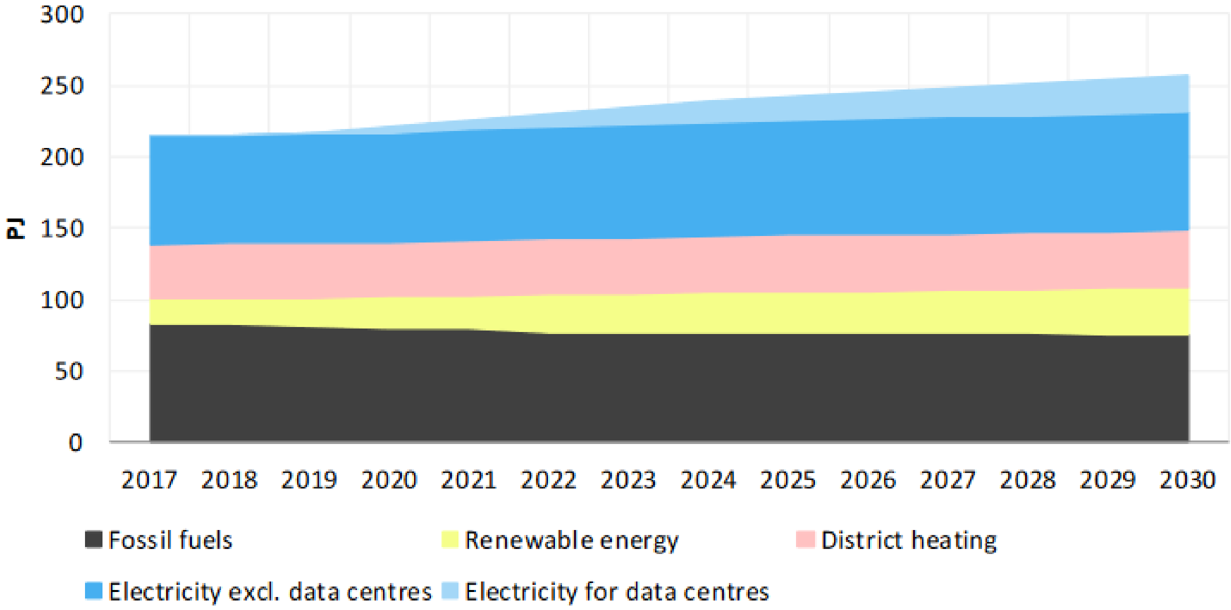


Figure 61: Final energy consumption by industry and services (2017-2030)

In terms of fossil fuels, Denmark is still counting on natural gas to favour its energy transition, in particular for hard-to-abate sectors. The country aims to produce renewable energy gas in the form of bio-natural gas. This means that biogas would be upgraded through blending with natural gas. At the same time, the consumption of coal is expected to be reduced by 90% in 2030 compared with 2017.

These forecasts, if unfolding, would put the question of storage at the heart of the Danish energy policy, as well as the problematic of heating. These two opportunities would have been further explored if ESTELA could have had meetings with the EFKW or the DEA.

8.3.2 Energy regulation in Denmark: towards new regulations for further renewable penetration

Forsyningstilsynet, the Danish Utility Regulator (DUR), supervises the electricity, gas and district heating utility sectors. It is currently working on an anthology on "Energy Regulation in the Green Transition", which should support a continuous reflection on the improvement of a regulation in line with an inclusive green transition[205]. Energy savings remain a priority in terms of actions for the DUR.

According to its NECP, Denmark aims to develop a new market model, with an improved regulatory framework, based on renewable energy sources in the most cost-efficient and innovative ways[206]. It also aims to take into account all challenges which such a model, largely based on renewables, triggers, in particular the question of secure systems and

[205] *Source: DUR, "T he Danish Utility Regulator launches anthology project with prominent researchers on energy regulation and the green transition", Press release, 15 June 2020*

[206] *Danish NECP, p.69*

flexibility. The Danish electricity market is open for participation from renewable energy, demand response and storage, including via aggregation.

In this new framework, the DSOs would be granted the role of "neutral market facilitators", through demanding flexibility. The country is thus aware of the importance for the market to accurately and adequately remunerate this characteristic of flexibility, as well as of the need to take into account the "rights and responsibilities of new players that may create value and provideflexibility in the electricity market"[207]. These changes are foreseen for the end of 2020.

Regarding tendering, Denmark started with technology specific support but is now involved in more multi-technology tenders, embracing a market-based approach. After a first wave of offshore wind tenders, new technology neutral tenders are expected between 2020 and 2024, including wave and hydropower technologies.

Electricity will be further incentivised, so that its use is promoted over the use of other energies, especially for the heating sector. This includes support to biogas until the end of 2020, when:

- Used to produce electricity or heat.
- Upgraded to biomethane.
- Used in hard-to-abate sectors (transport and industrial processes).

Solid biomass has also received strong incentives, in particular for the retrofitting of coal and gas power plants. Since April 2019, three new support schemes were introduced:

- A fixed premium is maintain for existing non-depreciated installations, through the depreciation period.
- A fixed premium has been introduced to support depreciated installations, based on the operating cost difference between the use of biomass and an alternative fossil reference.
- A grant pool has been established for new installations and gives the possibility of aid to new capacity for the production of electricity through green gases.

These current perspectives and priorities do not seem to leave many opportunity windows open for the development of CST technologies in the country. The use of technology neutral tenders, as well as favouring biomass for the conversion of fossil plants would difficult the competition for this technology.

8.3.3 Energy transmission system in Denmark: the role of Energinet

Energinet is the Danish TSO. It defines itself its mission as contributing "to converting energy systems with the aim of ensuring that citizens and businesses use renewable energy for everything, with a high level of security of supply and at an affordable price"[208]. It has a three-fold priority: renewable energy, high level of security of supply, and affordability.

[207] *Ibid.*

[208] *Energinet, Strategy: Winds of Change, December 2019, Energinet website [online]*

Energinet focuses on developing offshore wind, which represents a huge, not yet enough exploited, potential (40GW), combined with onshore wind and solar PV. Energinet foresees storage and system balancing as a challenge for the 2020 decade. However, this challenge is also perceived as one of the five expected effects of this strategy, allowing to achieve 100% renewable energy while ensuring security of supply. Four opportunities will be the focus of Energinet in the upcoming years:

- Sector coupling: use of green gases and conversion of electricity to hydrogen, heating and renewable energy-based fuels to decarbonise sectors such as agriculture and transport.
- Large-scale offshore wind power: this would contribute to achieve the global European targets.
- Solar and wind power on market terms: new solutions will be needed to take the most out of the further development of renewables.
- Collaboration with society: new infrastructures and technologies will be needed to accompany the green transition.

Regarding the need for new infrastructures, Energinet currently operates seven, amongst which five are related to electricity interconnections:

- Viking Link, interconnecting Denmark and Great Britain, to be commissioned by December 2023 and allowing the countries to share up to 1.4GW of electricity. It is recognised as a PCI.
- West Coast Line, to be commissioned by 2023, will interconnect Denmark and Germany with a 400kV double circuit, is linked to the Viking Link project and is also part of the PCI list.
- Kassø-Frøslev, a 400 kV overhead line PCI project between Denmark and Germany, which will allow to increase the transmission capacity at this border up to 2500 MW. It should be operational by the end of 2020.
- Kriegers Flak - Combined Grid Solution, the first offshore interconnector, should be operational at the end of the summer 2020. It will combine three wind farms, totalling a capacity of 936MW.
- Cobracable, commissioned in 2019, interconnects Denmark and the Netherlands by connecting the 400kV AC grid to the DC cable.

Energinet is also currently investigating the conditions for the construction of a new offshore farm, Thor, with a minimum capacity of 800 MW and maximum 1000 MW. It should be operational by 2027.

The priorities of the Danish TSO consider the necessity of developing storage, to face the increasing share of variable renewables in the energy mix of the country. However, as already mentioned in the section 8.3.1, it may be hard for the it may be hard for the CST sector to find an entry point here, if no support or interest from the main industrial players or policy-makers is shown.

8.3.4 Industry: heat applications as a success

Aalborg CSP is a Danish company involved in CSP projects around the world and specialised in the storage of energy. It has used its know-how to offer innovative solutions for district heating in Denmark. With a solid R&I implication, Aalborg CSP has also further developed the Thermal Energy Storage technology, to store wind and solar energy "at the lowest possible cost"[209].

Because of these characteristics, ESTELA deemed Aalborg CSP as a very relevant interlocutor to gather information on the Danish energy needs and potential for further development of CST technologies, in particular storage. Aalborg's experience shows that doors could be open in the Danish market for some parts of the CST technology value-chain, regarding district heating and decarbonisation of the industry sector.

However, despite several mail exchanges and one phone contact, no relevant information could be exchanged. ESTELA was redirected towards the Spanish branch of Aalborg CSP, which was not relevant in this frame. When it came to market information and contact details, no apparent interest in sharing contacts was shown without a tangible benefit in return.

[209] *Aalborg CSP website, "About Us" section.*

8.4 Expected next steps

The most detrimental effect on our research was the lack/level of response by the local company and entities in Denmark so far, in spite of our best efforts to explain the purpose of the project HORIZON-STE.

The next step would consist in updating and possibly extending the reported first assessments so far via renewed inquiries for interviews especially via the Danish representative in the SET Plan Steering Group.

Even with the active support of the EC services to reach Danish representatives in the SET Plan Steering Group or in the framework of the Implementation Working Group, our requests for contacts remained unanswered.

On the industry side, our efforts focused on getting an opportunity to capture the views and positions of the company Aalborg CSP which declared itself unavailable for providing the active contribution to our work. Nevertheless, the HORIZON-STE consortium will further seek for active contacts with the company, the more Aalborg CSP is very active and also successful in developing projects using concentrated solar technology.

8.5 Glossary

CSP	Concentrated Solar Power
CST	Concentrated Solar Thermal
DEA	Danish Energy Agency
DUR	Danish Utility Regulator
EC	European Commission
EFKM	Danish Ministry of Energy, Utilities and Climate
ENTSO-E	European Network of Transmission System Operators
EU	European Union
FiT	Feed-in-Tariff
FiP	Feed-in Premium
GJ	Giga Joules
GWh	Giga Watt hour
H2020	Horizon 2020
kWh	Kilo Watt hour
LCOE	Levelised Cost of Electricity
MS	Member States (EU)
MW	Mega Watt
MW_e	Mega Watt of electricity
MW_{th}	Mega Watt of thermal energy
NECP	National Energy and Climate plan
PPA	Power Purchase Agreement
PV	Photovoltaic
R&D	Research and Development
RES	Renewable Energy Sources
SET-Plan	Strategic Energy Technology Plan
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TSO	Transmission System Operator
TWh	TeraWatt hour

8.6 Appendices

8.6.1 Reference

Energy policy

Danish Energy Agency, Annual and Monthly Statistics, Figures 2018, DEA website [online]

Danish Energy Agency, Combined Heat and Power: A Progressive Way to Cogenerate Heat and Power [online]

Danish Energy Agency, Denmark's Energy and Climate Outlook 2019, October 2019, DEA website [online]

Danish Ministry of Energy, Utilities and Climate, Denmark: energy and climate pioneer Status of the green transition, April 2018, EFKM website [online]

Eurostat, Renewable energy in the EU in 2018, News release, 23 January 2020 [online]

Regulator

DUR, "The Danish Utility Regulator launches anthology project with prominent researchers on energy regulation and the green transition", Press release, 15 June 2020 [online]

TSO

Energinet, Strategy: Winds of Change, December 2019, Energinet website [online]

Industry

Aalborg CSP website, "About Us" section [online]

9 Chapter 9: Belgium

9.1 Structure of the document

The "Country Report – Belgium" aims to provide a global and structured approach of the country's profile regarding potential interest in STE, from funding mechanisms to commercial purposes.

The present document is based on the information gathered during the main phases of WP2 concerning:

– The expressed need for manageable RES energy by each country of focus and their respective strategies on its procurement.

– The possible changes in the framework conditions.

– The interest for and reception of potential solutions using STE.

Section 9.2 summarises the tasks which were carried out, describing first the initial plan and then the actual work carried out. This gives an overview of the intelligence collected and of the final key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given country. Activities typically involved:

– Meeting with relevant stakeholders, i.e. at Ministry, TSO and Regulatory Authority levels, as well as key players from local industries and civil society.

– Brokerage event and joint industry – R&I national events.

A deeper analysis of the context of the country is provided in 9.3, first from the political point of view (9.3.1) followed by a focus on the regulatory (9.3.2) and transmission (9.3.3) aspects. The overview of the current industrial landscape and its potential (9.3.4) closes this part. More precisely, the part aims at large to sketch the existing political strategies, the arising regulatory challenges and opportunities as well as to depict the current status and future requirements of the system in Belgium.

Based on these observations, key findings are drawn in 9.4. They highlight encountered challenges and existing opportunities for the development of STE technologies in Belgium.

Last but not least, as the study is still ongoing, part 9.5 suggests strategic next steps to continue opening doors for STE in Belgium, from an industrial point of view.

9.2 Summary of undertaken activities

Belgium has been under the scope of analysis since September 2020. The Covid-19 global pandemic has slowed down the process. As the HORIZON-STE consortium does not include any Belgian partner, ESTELA could rely on the help from one of its member John Cockerill, a well-established industrial actor in the STE sector. John Cockerill helped ESTELA draw a first sketch of the Belgian energy landscape, as well as identify relevant interlocutors at regional and federal levels.

9.2.1 Foreseen activities and implementation challenges

To favour a sustainable launch of STE in studied countries, ESTELA designed a general process unfolding in three steps with flexibility to adapt to specific country challenges:

PHASE 1	
BACKGROUND RESEARCH AND FIRST MEETINGS	
General aim	To understand the need for manageable RES energy and Belgium's strategies on its procurement / possible changes in the relevant framework conditions
Encountered challenges	– To find the right interlocutor – Low answer rate to interview requests – Mixed information received from different interlocutors
Applied mitigation	– Help from John Cockerill to identify relevant stakeholders – General translation of official documents from French to English – Confrontation of different sources with the official source
PHASE 2	
BROKERAGE EVENT	
General aim	Assessment and presentation of potential solutions using CSP/STE
Encountered challenges	– Outbreak of covid-19 global pandemic – Highly disaggregated responsibilities and competencies across the administrative layers of the country (e.g., federal, provinces)
Applied mitigation	– On-line meetings with national stakeholders
PHASE 3	
JOINT NATIONAL EVENT	
General aim	Focus on possible synergies and macro-economic value
Encountered challenges	– Outbreak of covid-19 global pandemic – Not enough data collected yet
Applied mitigation	– Awaiting the end of the pandemic to evaluate the possibilities

9.2.2 Carried out activities – Industry perspective in Belgium

LIST OF ACTIVITIES	TIMELINE
BACKGROUND RESEARCH	Phase 1 Sept.-Nov. 2020
Aim: To collect relevant information to better understand the energy landscape in Belgium, the potential challenges for the development of STE and the needs of the country	
Description Desk research: Collect of information based on available information on official websites (e.g.: Wallonian Directorate for the Promotion of Renewable Energy [SPW Energy], Commission for Electricity and Gas Regulation [CREG], ELIA, European Commission, John Cockerill …), academic studies or reports by consultancies Stakeholder mapping: Analysis of the specific relevant departments and actors for each identified target group Exchanges with John Cockerill on relevant contacts and existing knowledge of the local situation	
PRELIMINARY TALKS	Phase 1 Sept.-Nov. 2020
Aim: To collect direct feedback regarding needs in terms of energy and more precisely manageable renewable energy sources (RES), the current and future energy strategies, the procurement system and the possible changes in the relevant framework conditions	
Description Ideally, this phase aims to establish a first physical contact with the three key stakeholders in Belgium regarding energy policy, namely the TSO, the Ministry and the Regulatory Authority. ELIA: Interview with representatives of the Belgian TSO SPW Energy: Interview with representatives of the Walloon region	
PHONE INTERVIEWS	Phase 1 Sept.-Nov. 2020
Aim: To collect more targeted feedback on political, industrial and economic factors regarding the development of Belgium's energy strategy and potential need for manageable RES	
Description John Cockerill: Interview with a representative of John Cockerill, also Board Member of ESTELA	
BROKERAGE EVENT	Phase 2 Not applicable.
Aim: To have a broad overview of STE perspectives in Belgium through existing and potential solutions using STE, from both the R&I and industry sides.	
Description Not applicable.	
NATIONAL EVENT	Phase 3 Not applicable
Aim: To provide a space for actors from the entire STE value-chain to meet and talk through their specific needs and expectations regarding the support of Belgian STE industries involved in foreign STE projects and concentrated solar thermal technologies for industrial heat. To focus on possible synergies and macro-economic value. Description Not applicable.	

9.3 Overview of the context in Belgium

The desk research and first preliminary interviews helped ESTELA refine its understanding of the energy context in Belgium. The following subsections were enriched thanks to ESTELA's own desk research and inputs from John Cockerill, the sole Belgian company involved in CSP.

9.3.1 Energy policies and the place of STE in the Belgian landscape

9.3.1.1 Current energy mix in Belgium

Belgium remains highly dependent on fossil fuels, which represent more than three quarter of the total final energy consumption in 2019, as shown in Figure 62. Looking closer at the breakdown of data per sector presented in Table 41, the industry and transport sectors represent almost half of the final energy consumption in Belgium, closely followed by households. Figure 64 details the breakdown of energy sources used per sector.

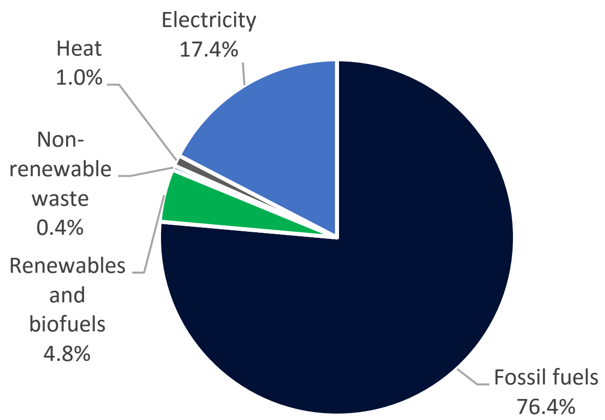


Figure 62: Share of energy sources in total final energy consumption (source: Statbel)

Sector	Final consumption
Industry	26%
Transports	22%
Other	33%
Commercial and public services	11%
Households	20%
Agriculture and forestry	2%
Non-energy use	19%
Total	100%

Table 41: Breakdown of energy consumption per sector (2018)

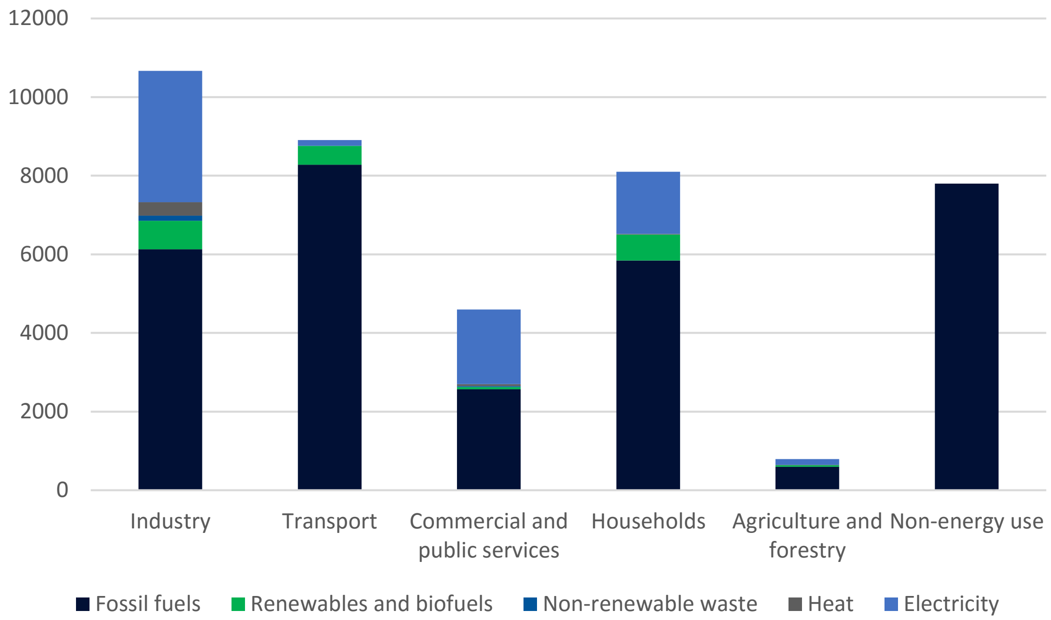


Figure 64: Share of consumed energy sources per sector (in ktoe)

In those three main consuming sectors, fossil fuels represent at least half of the consumed energy, while renewable energies remain below 10% (Figure 63). Electricity represents 31% of the industry consumption and 20% of the household consumption.

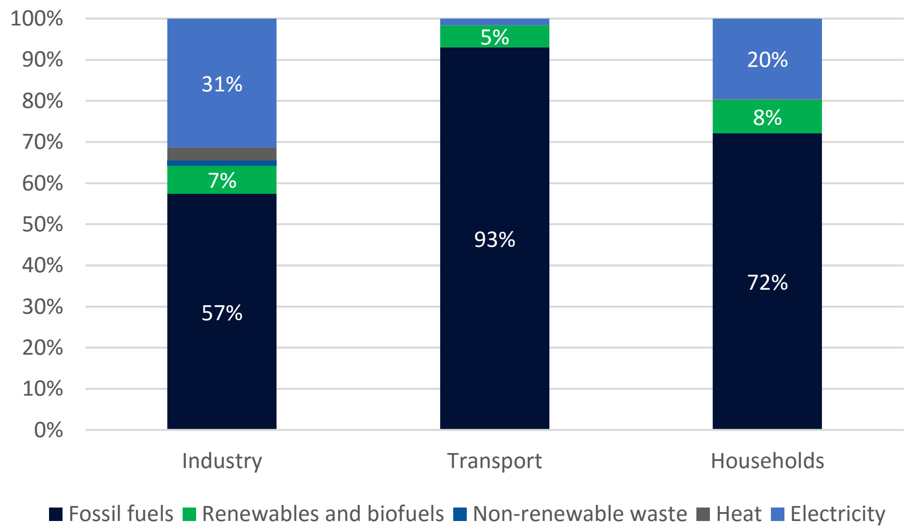


Figure 63: Share of fossil fuels in three main energy consuming sectors

In 2019, Belgium had an installed capacity of 16,452.1MW dedicated to electricity production, whose composition is detailed in Figure 65. Belgian electricity production capacity highly relies on nuclear and natural gas, which represent more than two third of the installed capacity. However, nuclear power should be phased out by 2025, according to the decisions of the Belgian government. Regarding power generation, for the year

2019, renewables represented 21% of the final electricity consumption, according to the Belgian Observatory for Renewable Energies[210].

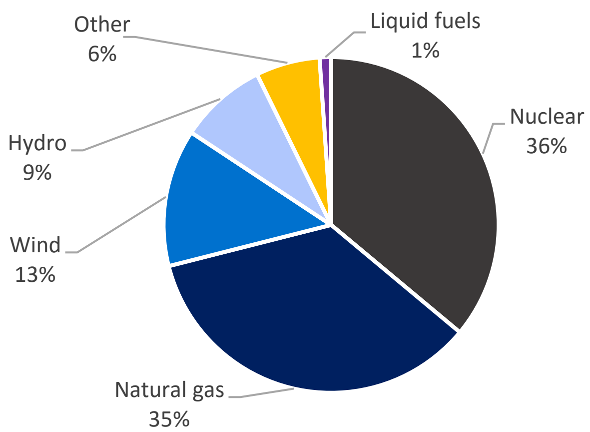


Figure 65: Installed capacity for electricity production in 2019 (source: Elia)

Figure 66[211] details the monthly breakdown of energy sources used in electricity production and clearly shows the predominance of nuclear and gas in the Belgian electricity generation. Main renewable sources include wind and biomass (included in "other") and remains fairly constant over the year.

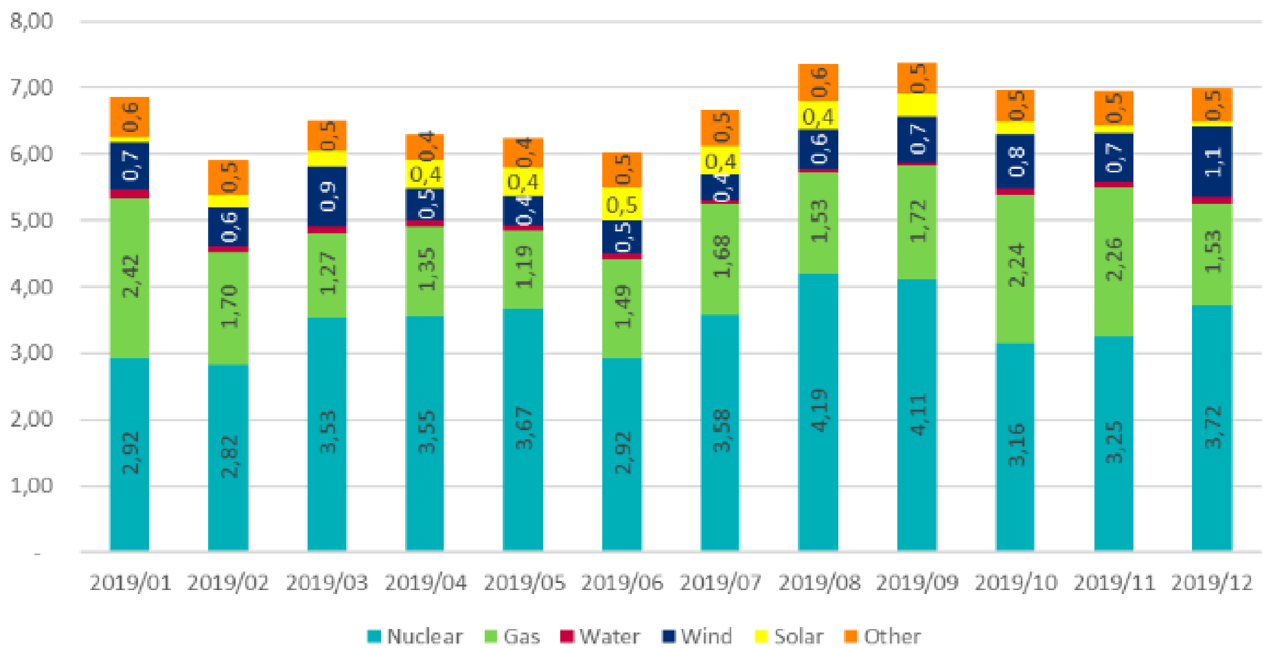


Figure 66: Monthly electricity production in 2019 (source: Elia and CREG)

[210] 210 See https://energiecommune.be/statistique/energie-renouvelable/

[211] *Please note that "Solar" refers to solar PV*

Looking at import and export of energy, Belgium has exported more electricity than it has imported in 2019, as can be seen in Table 42 below. This higher share of exportation in 2019 can be explained by a rather sunny and windy year in the country, coupled with less breakdowns of the nuclear fleet. Connections with neighbouring countries include: the United Kingdom, the Netherlands, France and Luxembourg.

Belgian energy balance in 2019	
Import	12,728
Export	14,545
Net import	-1,816

Table 42: Belgian energy balance in 2019 (source: Elia)

Finally, Belgium considers the potential of the hydrogen market very important. As part of the Pentalateral Energy Forum (which gather the Netherlands, Austria, Germany, France, Luxembourg, Switzerland, and Belgium), Belgium has embraced a long-term vision for 100% renewable hydrogen, which would contribute to a European integrated energy system in which seasonal energy storage has a role to play[212].

9.3.1.2 The Belgian NECP

Based on the Commission's assessment of Belgium's National Energy and Climate Plan (NECP), the document remains too unambitious. Starting with its initial 2020 targets, Belgium is late in terms of share of RES in the gross final energy consumption. Expected to reach 13% by 2020, it only accounted for 9.4% in 2018. On the contrary, when it comes to the share of RES in electricity generation, Belgium is on track to reach the 2020 target of 21%.

However, the 2030 targets set by Belgium are deemed "unambitious" by the Commission, particularly regarding RES targets[213]: only 17.5% of RES in the gross final consumption. This target is below the indicative share of 25% initially indicated by the Commission and the indicative trajectory shows that it would remain below the 2020 level until 2025. Regarding the electricity production, RES should cover 37.4% of the generation, which aligns with the general EU objectives. It would be mostly achieved through offshore and onshore wind, as well as PV.

The Commission's assessment also pointed out regulatory barriers to investment in clean energy production and use. For instance, Belgium only plans an action plan for a gradual removal of fossil fuel subsidies around 2021. Regarding the internal energy market, Belgium did not indicate specific policies or measures which would target, amongst topics of interest for us:

- Non-discriminatory participation of renewable energy.
- Demand-response.
- Storage.

[212] *Source: Joint Political Declaration of the Pentalateral Energy Forum*

[213] *Source: Commission Staff Working Document, Assessment of the final national energy and climate plan of Belgium, SWD(2020) 900 final, October 2020*

- Aggregation.
- competition of the retail energy market.

However, it is worth noting the discussion on the introduction of a climate-friendly energy taxation by 2021, which would benefit RES deployment.

On the energy security side, Belgium plans to phase out its nuclear fleet and has quantified the need for flexibility this will create, planning a reform of its electricity market. The 6GW of nuclear should be replaced with flexible capacity, storage, and renewable energy sources, but no detailed information is mentioned in the NECP. The Commission specifically pointed out the lack of development regarding the sources of flexibility. This may be of interest for thermal energy storage (TES). In parallel, Belgium has decided to introduce a technology-neutral capacity remuneration mechanism, to guarantee the security of supply. A CRM task force has been created in March 2019 to discuss the design of this mechanism[214]. It has also set a target of 33% of electricity interconnectivity, which should reinforce security of supply.

Belgium foresees an increase of emissions from energy industries due to an increased use of natural gas power plants in the different scenarios imagined by the Federal Planning Bureau[215]. The share of natural gas would be between 41% and 49% in 2030.

9.3.1.3 Existing projects for renewable industry heat

A Concentrated Solar Thermal pilot plant has been inaugurated in the Port of Antwerp in October 2019. Steam is produced by 1,100m² of parabolic troughs, coupled to insulated containers, which will allow to annually replace 500 MWh of gas consumption. The Antwerp plant is part of a bigger project, involving a total of three pilot installations with solar reflectors in Flanders. They are expected to generate between 1,260 and 1,390 MWh of heat per year[216]. According to the CEO from the Flemish company Azteq, which installed the application, "there are also plans for projects in the Netherlands, France, Germany, Austria and Spain". This can potentially turn Belgium into a leader in the solution and attract more interest.

Another CST plant has been installed in the premises of Proviron chemicals in Oostende, Belgium to generate steam for its industrial process. The plant covers an aperture area of 1,100 m² and has a capacity of 500 KW_{th}, enabling the savings of 105 tons CO_2 per year[217].

[214] *See https://www.elia.be/en/electricity-market-and-system/adequacy/capacity-remuneration-mechanism*

[215] *See https://www.plan.be/uploaded/documents/201504270958240.WP_1503_10941.pdf*

[216] *See https://newsroom.portofantwerp.com/pioneering-eco-friendly-project-for-solar-heat-in-the-port-of-antwerp*

[217] *See https://www.bves.de/wp-content/uploads/2022/04/20220331_Slides_BVES_DCSP_Enabling_Energy_Transition_with_Thermal_Technologies.pdf*

9.3.2 Energy regulation in Belgium

Belgium is a federal state, which delegates principal responsibilities for designing and implementing policies for energy efficiency, renewables (except offshore energy), non-nuclear energy research and development and market regulation to the regional governments of Flanders, Wallonia and Brussels Capital. The federal government, however, is responsible for electricity transmission and large-scale generation, transport of natural gas and oil; nuclear energy, security of energy supply, price policy, consumer protection, the national rail system, transportation fuels; offshore energy and energy research, development and demonstration related to its competences.

At the state level, energy affairs are tended by the Directorate-General for Energy, part of the ministry of Federal Public Service for Economy, SMEs, Self-employed and Energy[218]. The Energy Consultation[219] is a formal body responsible for coordinating all energy policy affairs between the federal and regional governments[220]. Furthermore, the country has four energy regulators:

- The federal regulator, the Commission for Electricity and Gas Regulation (CREG)[221].
- The Flemish regulator, the Flemish Regulator of the Electricity and Gas market (VREG)[222].
- The Walloon regulator, the Walloon Energy Commission (CWaPE)[223].
- The Brussels regulator, Brussels Gas Electricity (BRUGEL)[224].

All four regulators are independent, both from market and policy perspective. The authorities don't follow guidance from ministers or policy makers; however, they do have to comply with general policy directions. The key responsibility of the four regulations is to set the tariff methodologies and approve the grid tariffs from the grid operators.

9.3.3 Energy transmission system in Belgium: the role of Elia

Fossil fuels will still occupy a very important position in the Belgian energy landscape until 2050. With the closing of nuclear power plants by 2025, which represent half of the voltage control, space for new gas stations will probably be made. Indeed, Elia plans to cope with the closing of nuclear plants mostly with gas-fired power plants. Capacity remuneration mechanisms are currently discussed and will be enforced to replace the nuclear capacity and should be open to all types of technologies.

[218] See https://economie.fgov.be/en

[219] See https://www.conseil-energie.be/

[220] Available in full here: https://iea.blob.core.windows.net/assets/638cb377-ca57-4c16-847d-ea4d96218d35/Belgium2022_EnergyPolicyReview.pdf

[221] See https://www.creg.be/nl/cregscan#/

[222] See https://www.vreg.be/en

[223] See https://www.cwape.be/

[224] See https://www.brugel.brussels/

According to Elia, the use of renewable energy sources should be mainly focusing on electricity, since electricity is the most efficient form to use RES. It avoids losses through conversion and 35% to 40% of the energy demand could be thus met locally. However, the full electrification of all processes and sectors is not yet possible, nor advisable for now. As Elia underlines it, some processes still highly rely on molecules, for instance for activities linked to feedstock, high temperature industrial processes, or maritime and aviation shipping.

Elia estimates that around 50% of the system cannot be electrified. It is in these processes that Elia foresees a role for hydrogen – not for the electricity grid. Indeed, producing hydrogen to inject in the electricity grid would not be cost-efficient, particularly since producing green hydrogen would require using RES which would normally be used for electricity production. The role of back-up for the grid will still be undertaken by fossil fuels. According to Elia, the problem of intermittency is currently a non-existing problem, which will only materialise in the last step of the decarbonisation of the system. Decarbonisation is the priority for Elia, not the maintaining of existing gas pipelines.

To achieve a high decarbonisation, Elia is currently striving to achieve a high energy efficiency, to be in line with the Belgian and EU energy targets for 2030. To reach this goal, the Belgian TSO is betting on digitalisation as its best tool. Indeed, with a projection of more and more decentralised energy production, due to more variable and local RES which should cover 80% of Belgium's needs by 2050. Digitalisation should help monitor the efficient use of energy, sending signals to say when it is possible to consume, through price signals. This optimisation will not only help coping with the complexity of the system, but also reduce the need for storage, according to Elia, since digitalisation would help better match production and consumption. There is thus very little use of thermal storage for the grid, but it may be interesting for process heat or power fuels production.

As 20% of its energy needs would not be covered, Belgium would have to import energy. It has currently interconnections with four of its neighbours: the UK, France, the Netherlands, and Luxembourg. In 2019, Belgium exported more to the UK and Luxembourg than it imported., imported slightly more from the Netherlands than it exported, and almost imported the double of what it exported to France.

The first interconnector between Belgium and Germany has been inaugurated in November 2020. This new line has a 1,000 MW capacity[225].

9.3.4 Belgium as a potential key industry player for STE and concentrated solar at large

ESTELA had a discussion with John Cockerill, one of its members and a key actor on the STE sector in Belgium. Involved in solar receivers and steam generators, John Cockerill has contributed to the construction of major CSP plants in the world, such as the direct steam solar receiver for Khi Solar One in South Africa, molten salt solar receiver for Cerro Dominador in Chile, molten salt solar receiver for Haixi Luneng in China, molten salt solar

[225] *See https://www.elia.be/fr/infrastructure-et-projets/projets-infrastructure/alegro/20201109-alegro-inauguration-fr*

receiver for Dubai Solar Park Phase IV in UAE and molten salt solar receiver for Redstone in South Africa[226].

Thanks to its good intelligence of the Belgian context and its knowledge of the technology, John Cockerill could describe the ideal pattern for a further development of the STE value-chain in Belgium. Given the strong predominance of gas in Belgium, and the strategy aiming to reinforce the use of this energy source as described in the NECP, there is no space for the use of STE for electricity, even in a scenario import. Indeed, not only the solar resources in Belgium do not allow a direct production of electricity with CSP in the country, but the political strategies do not value any green manageable baseload at the moment.

However, the TES part of the CSP plant can be of interest for Belgium, and even more for its industry. The high penetration of variables in the wholesale market would indeed serve the emergence of long duration storage projects, over eight hours.

John Cockerill is currently working on producing high-temperature storage solutions and steam for the industry sector. Given the presence of many hard-to-abate industry sectors in Belgium, the decarbonisation of industrial heat is a major issue, which opens a viable market for heat in the country, according to John Cockerill.

[226] *https://johncockerill.com/wp-content/uploads/2022/01/solar-thermal-storage-def-HD.pdf*

9.4 Key findings

9.4.1 A sense of export interest for Belgian industries exists

The SPW issues calls for projects according to priority topics defined according to the regional policy, in line with the Plan and with the Horizon 2020 calls for projects in energy. The SPW looks primarily into coherence between the Walloon and European research.

It aims to develop elements in line with other European partners, to better access the European market.

9.4.2 First interesting process heat deployments caught the attention of the Ministry

Currently there are two CST plants in Belgium that have caught the attention of the Ministry, i.e. one in the Port of Antwerp and another one in the premises of Proviron chemicals in Oostende. Even though these reflect a starting point for the transition of the industry in Belgium towards decarbonisation, there are still major challenges to address:

- There are many cement and lime industries which use calcium oxides: their processes should be decarbonised.
- Leilac Project, a demonstration project led by a European consortium in Lixhe (Liège region), aims to build a furnace which would isolate calcium oxides from the heat generated by natural gas or other combustible. The aim is to easily catch CO2 emissions.

9.4.3 The increase of VRES in the system will require a shift in the consumption paradigm

There will be a paradigm shift:

- Today, the production is following the consumption.
- In the future, they won't be able to control the production of VRES.
- When there is too much VRES in the system, then Elia can do curtailments. The problem is when there is too little.
- The paradigm must shift towards a consumption which follows the production.

9.5 Conclusions and recommendations

Despite the limited solar resources in Belgium, there is a large industry player in the country with worldwide references regarding RES projects in general, and CSP projects in particular. More specifically, John Cockerill is a world class supplier of CSP projects, and as such, its views for the development of the CSP/T sector are of particular importance.

Having in mind that, on the one hand, the essence of NECP is to reflect the national energy policy ambitions of a whole country, and on the other hand, the natural solar resources in Belgium will prevent the construction of fully fledged large CSP plants, it is understandable that the Belgian NECP leaves no room for STE.

However, the TES technology of CSP plants, for which John Cockerill demonstrated in world markets their international competitiveness (see section 9.3.4), should be better highlighted since it serves the needs for long duration storage to accommodate high levels of intermittent RES in the electricity system. Importantly, the challenge of decarbonising the industry sector opens the door to CST technologies for the market of process heat in the country.

9.6 Glossary

CSP	Concentrated Solar Power
EC	European Commission
EU	European Union
H2020	Horizon 2020
ktoe	Kilo Tonne Oil Equivalent
kWh	Kilo Watt hour
MS	Member States (EU)
MW	Mega Watt
MWh	Mega Watt hour
NECP	National Energy and Climate plan
PV	Photovoltaic
R&D	Research and Development
R&I	Research and Innovation
RES	Renewable Energy Sources
SET-Plan	Strategic Energy Technology Plan
STE	Solar Thermal Electricity
TES	Thermal Energy Storage
TSO	Transmission System Operator

9.7 Appendices

9.7.1 References

Brussels Gas Electricity website [online]

Commission for Electricity and Gas Regulation website [online]

Elia website [online]

Enabling Energy transition with Thermal Technologies, Dr. Joachim Kruger "How to reduce gas consumption: Solar process heat for industries and utilities – leteste developments & projects" [online]

Energie Commune website [online]

Federal Planning Bureau, "2030 Climate and Energy Framework for Belgium" [online]

Flemish Regulator of the Electricity and Gas market website [online]

International Energy Agency, "Belgium 2022 – Energy Policy Review" [online]

John Cockerill, "Solar & Thermal Storage. Your solution provider for dispatchable carbon free energy" [online]

Ministry of Federal Public Service for Economy, SMEs, Self-employed and Energy website [online]

Port of Antwerp, "Pioneering eco-friendly project for solar heat in the port of Antwerp" [online]

Walloon Energy Commission website [online]

9.7.2 Meeting guidelines

See APPENDIX.

9.7.3 Interview guidelines

See APPENDIX.

10 Chapter 10: Cyprus and Switzerland

10.1 Structure of the document

The "Other Country Reports – Cyprus and Switzerland" aims to provide a global and structured approach of the country's profile regarding potential interest to STE, from funding mechanisms to commercial purposes.

The present document takes into account the relevant information gathered during the main phases of WP3. Since there is no partner neither from Cyprus nor from Switzerland, information for the R&I part were drawn from the SFERA-III Concept note for Cyprus and communication with the SFOE.

Section 10.2 summarises the tasks which were carried out on the R&I side. This gives an overview of the intelligence collected and of the final key stakeholders and serves as a basis for spotting opportunities and challenges for STE in the given countries. A deeper analysis of the R&I context of each country is provided in section 10.3 and 10.4 respectively.

10.2 Summary of undertaken activities

Cyprus and Switzerland have been under the scope of analysis from November 2021 until March 2022. The Covid-19 pandemic has slowed down the working process. Notably, ESTELA has collaborated with ENEA and DLR regarding the information related to R&I. Furthermore, as the consortium does not include any Cypriot or Swiss partner, the HORIZON-STE partners received a strong support from the SFERA-III project and the SFOE to maximise impacts and meaningful results.

The following chapters will describe the work undertaken to analyse the challenges and opportunities met in these two countries.

10.2.1 R&I methodology

To have a wide overview of the R&I landscape of Cyprus and Switzerland the following activities were carried out:

<table>
<tr><th colspan="2">List of activities</th><th>TIMELINE</th></tr>
<tr><td colspan="2">Documentation phase</td><td>Nov. 2021 - Mar. 2022</td></tr>
<tr><td colspan="3"><u>Aim:</u> to collect the information available about R&I in Portugal related to CST technologies (stakeholders, research centres, funding sources,..)</td></tr>
<tr><td>Description:</td><td colspan="2">Since there is no Cypriot and Swiss partner in the HORIZON-STE project and taking into consideration (i) the synergies between the country report for Cyprus and the content of the National Concept Note for the country to be elaborated within the framework of WP3 in the European SFERA-III project, and (ii) the on-going R&I activities in these two countries, people from the SFERA-III project and the SFOE were contacted, thus getting the intended information about research centres, research facilities and funding sources for R&I activities related to CST technologies and applications.</td></tr>
<tr><td colspan="2">Processing of information and writing of report</td><td>Jan. 2022 – Mar. 2022</td></tr>
<tr><td colspan="3"><u>Aim:</u> to write the sections devoted to R&I in this Country Report of Cyprus and Switzerland</td></tr>
<tr><td>Description</td><td colspan="2">All the information collected during the documentation phase was analysed and processed by ESTELA, ENEA and DLR in order to get the R&I landscape of Cyprus and Switzerland for CST technologies and applications, especially those directly related to the SET Plan for CSP.
The updated list of national and European R&I projects prepared by CIEMAT in 2021 within the EERA Joint Programme of CSP with the inputs delivered by the members of this EERA JP was also analysed to see the R&I activities currently underway in Cyprus and Switzerland and the topics covered.</td></tr>
</table>

10.3 Overview of the context in Cyprus

10.3.1 R&I landscape

This section presents the main outcome of the background research and the analysis of the information and opinions collected from Cypriot Research and Innovation (R&I) entities involved in concentrated solar technologies (CST). It is divided into the financial framework, the ongoing activities of Cypriot R&I entities and the strategies defined in Cyprus that have an impact into the focus of research and funding.

10.3.1.1 Cyprus' R&I energy support programmes

The latest funding initiative for Research, Technological Development and Innovation in Cyprus used to came through Research Promotion Foundation's (now called Research and Innovation Foundation (RIF)) RESTART 2016-2020 Programmes, which had a total budget of €100m to assign in various beneficiaries (research and academic institutions, enterprises and other organisations) within this timeframe. It does not allocate a specific amount to CSP/CST, but funds can be channelled through its energy-related projects (energy is one of the priority sectors for Programmes falling under Pillar I: Smart Growth) that span from infrastructures to desk-based research, with a special focus on Interdisciplinarity. The main thematic priority sectors of research for Cyprus are chosen by local stakeholders via field studies, focus groups meetings etc. and approved by the Council of Ministers are documented in the 'Smart Specialisation Strategy' for Cyprus. In this, energy is a 'dominant priority sector', which means that it will attract a large percentage of the funds. No new programme for the funding period after 2020 exists, but a few isolated calls that have been published follow the same formula as above.

The main external funding umbrella of Horizon Europe and its previous incarnations (H2020, FP7, FP6, etc.) from the EU play a large role in energy research in Cyprus and are the main cross-national funding pillars. It's worth noting that for every Euro that the country has contributed to the budget of the Programme, it managed to secure via successful proposals more than three Euros, thus ranking first among the EU member states.

Cyprus, via RIF, also participates in SOLAR ERA-NET, a network bringing together more than 20 Research Technology & Development (RTD) and innovation programmes in the field of electricity generation from solar energy, in particular from the use of photovoltaic (PV) and CSP technologies in the European Research Area. The SOLAR ERA-NET was established within a FP7 ERA-NET project and continues its activities in the Co-fund ERA-NET scheme under the Horizon Europe Framework Programme. The RIF participates in all Joint Transnational Calls announced by the network acting as the national funding mechanism, channelling funds to Cypriot beneficiaries.

10.3.1.2 Existing R&I activities (list of current projects and initiatives) related to CST technology

At the research side of the spectrum two institutions are active, one is the Cyprus Institute, which has a number of R&Is used as experimental platforms for scientific work on CSP/CST, while the other is the Cyprus University of Technology with the Archimedes Solar

Energy Laboratory and the Solar Simulator Laboratory, for indoor testing of solar systems and components under controlled conditions.

The Cyprus Institute (CyI) is the main actor in CSP/CST research in Cyprus, mainly dealing with solar thermal technologies for island environments, and the development of technologies for the future of related technologies. The Cyprus University of Technology is also experimenting with solar thermal systems of low and medium temperature. The University of Cyprus has also developed techniques suitable for the numerical modelling of solar thermal storage and high temperature solar thermal systems.

The current research infrastructure at the Cyprus Institute is as follows:

- Fresnel system: A novel CST system with approximately 170 m^2 of Linear Fresnel Reflectors has been constructed at the Nicosia Athalassa Campus of CyI in Nicosia. Its aim is to supplement the existing heating, ventilation and air-conditioning system of the nearby Near-Zero Energy Building. It stores excess energy in a specially designed storage system to supply the building thermal energy needs beyond its normal operating hours based on pressurised water; There also plans to feed electric power to the building via an array of PV cells installed on the underside of the Fresnel mirrors, controlled by a centralised building management system. The expertise developed with the construction and operation of this system can be directly transferred to an industrial Solar Heat for Industrial Purposes (SHIP) system setting with a temperature operating within the range from about 130°C to close to 400°C, occupying a large portion of the gamut of possible industrial applications.
- Platform for Research, Observation, and Technological Applications in Solar Energy (PROTEAS): The mission of the PROTEAS facility, is to pursue research and development of solar technologies, CSP and Solar Desalination of Sea Water in particular. This coastal solar experimental field facility is a testing field for devices intended to be used in coastal/island conditions, and for solar desalination technologies. The facility consists of 50 heliostats designed by the Australian National Research Agency (each with a reflective area of 4.8 m^2), a novel solar receiver, a thermal molten salt thermal energy storage, a steam generation generator and electricity production power block, and a Multi-Effect Distillation device system for sea water desalination. The design principles of the PROTEAS facility are geared towards electricity generation and desalination, with many the lessons learned from the study of optics, efficiency, operation in coastal environments and system integration. There are immediate plans for expansion of the facility into a multi-modal generation mode using PV, wind and (in the future) biomass units, serving a number of different end-user needs ranging from electricity generation, to desalination, to industrial heat, to space heating and cooling etc.
- The Athalassa Heliostat Testing Field: The Athalassa's Heliostat Testing Laboratory is an advanced heliostat testing facility and was established in 2013 at CyI's main campus in Nicosia with the objective to experimentally test heliostat performance and heliostat tracking, heliostat characterisation etc. The facility consists of two heliostat test benches in an outdoor environment.
- Thermal Energy Storage Laboratory: Key to the research programme of the Energy Systems division is the development of the Thermal Energy Storage Laboratory,

located at the Athalassa Nicosia Campus, where advanced thermal energy storage concepts are developed and tested. The lab has been operating since early 2013, with significant work (in close collaboration with ENEA) in characterising the thermal decomposition of nitrate salts.

- Solar Energy Desalination Laboratory: The Solar Energy Desalination Laboratory has been operating at the Athalassa Campus since 2010. Significant work is being carried out on designing, constructing and evaluating the performance of a Multiple-Effect Distillation unit for seawater desalination under variable operating conditions, such as the number of effects used, the temperature of the incoming seawater, the characteristics of the heat input provided to the system, and the amount seawater provided, aiming to determine optimal operating conditions. This lab can be relevant in case the SHIP application requires the supply of fresh water (e.g. in industrial washing) that can be supplied from such a system.

The current research infrastructure at the Cyprus University of Technology is as follows:

- Archimedes Solar Energy Laboratory: This is a laboratory equipped with all necessary equipment to perform experiments with solar energy systems (both thermal and electrical) and include radiation, wind speed and temperature measuring equipment, data acquisition systems, thermal camera and various types of solar collectors (flat plate and a small parabolic trough) and a small PV system with three different PV technologies based on polycrystalline, monocrystalline and amorphous silicon solar cells.
- Solar Simulator Laboratory: The main piece of equipment of this laboratory is an indoor 12kW solar simulator with which a large variety of experiments can be performed under control conditions. The simulator can move up and down, can take various inclinations and all its 20 lamps can be controlled individually. The laboratory includes also a sky simulator to simulate the passage of the solar radiation trough the vacuum in its way from the sun to earth.
- Solar Cooling and Heating System: This is a 300 kW operating solar cooling and heating system based on the LiBr technology. It is equipped with a 300 m^2 evacuated tube collector system and three absorption chillers. Part of the cooling process is satisfied with a geothermal system to reduce the use of cooling tower.

The current research activities at the University of Cyprus include:

- Within the Department of Mechanical and Manufacturing Engineering, UcyCompSci has developed techniques that can be applied to simulate numerically solar thermal storage using different storage liquids and high temperature solar thermal systems. Using CPU and GPU High Performance Computing and Computational Fluid Dynamics, the performance of solar thermal components (or systems) can be examined numerically at extreme conditions.

10.3.1.3 Energy policies and political strategies in the Cyprus landscape

In Cyprus, the promotion of RES and Energy Savings is achieved through the 112(I)/2013 Law. The fund associated with it is financed by a levy of 0.5 eurocent per kilowatt-hour on electricity consumption for all final consumers. In general, the purpose of the fund is to support the efforts of the Ministry of Energy, Commerce and Industry to achieve the RES and Energy Efficiency targets of 2020 and the new targets set for 2030. The legislation as it stands does not target CSP/CST explicitly. CSP and CST are mentioned however in the latest National Energy and Climate Plan (NECP) for Cyprus, in the context of the ability to combine generation with thermal storage, or for solar cooling applications. While the contribution to the energy mix of Cyprus in 2030 is relatively small, it is envisaged that CSP & storage can play a significant role in a decarbonised economy in the years up to, and especially after 2030 leading up to carbon neutrality in 2050.

On the CST side, and complementing the Law on Energy Efficiency of Buildings (No. 210(I)/2012) a series of decrees have been passed 2011 - 2019 on:

- Mandatory inspections of heating (>20 kW) and air conditioning (>12 kW) systems.
- Efficiency and size of heating, cooling, hot water and large air conditioning systems.
- Requirements for installing certified heat pumps and solar thermal equipment as well as performance requirements for biomass heaters and boilers.

The Cyprus government has adopted a number of legal acts to regulate the establishment and work of Energy Service Companies (ESCOs) with the main legislative measures being the law on Energy Efficiency in End Use and Energy Services Law and subsequent amendments (N53 (I) / 2012, RRA 210/2014 and N56 (I) / 2014). Cyprus also complies with article 18 and other relevant articles of the EED and has created the necessary regulatory framework conditions for ESCO companies operating in Cyprus. CSP/CST projects can be further promoted once they become commercially available from individual companies by taking advantage of the benefits of an ESCO agreement. In some cases (and especially for public sector projects), such agreements can be further supported by bilateral governmental agreements.

As of the middle of 2020, there were no direct incentives in place for the promotion of CSP/CST applications in Cyprus. There was support for heating and cooling using solar technologies under the scheme *"I save, I upgrade"*. The support scheme was opened to all technologies including CST. Most of the applications received were referring to solar thermal collectors for space heating. The grant was covering 50% of the investment and up to 15,000 Euro per building.

The Renewable Energy and Energy Conservation fund ("The Fund") that is responsible by law N.112/2013 for the promotion of RES and Energy Efficiency, is currently examining the most cost-effective applications to promote both RES and Energy Efficiency measures. The Government is in a transitional phase to more market-oriented financial support schemes. The only support scheme for the time being regarding solar thermal applications is the support scheme for the installation/replacement of Domestic Solar Water Heaters.

Energy Fund of Funds Cyprus:

- Building on the suggestions of the relevant Ex Ante Assessment for the use of Financial Instruments in the context of the European Structural and Investment Funds (ESIF), the Directorate General for European Programmes, Coordination and Development and the European Investment Bank (EIB) have entered into a Funding Agreement on 18 December 2018, whereby the Republic of Cyprus appointed the EIB to manage and operate an instrument in the fields of energy efficiency and RES.

- On this basis, the Cyprus Energy Fund of Funds has been set-up as a separate block of finance within the EIB.

The Cyprus Energy Fund - will primarily comprise two sources of public funding, namely:

- ESIF 2014-2020 and national co-financing (EUR 40m).
- Additional national contributions sourced from an EIB sovereign loan (EUR 40m).

Moreover, The Fund has a new scheme providing grants for the installation/replacement of solar water heating systems in existing houses which had a building permit issued before 21.12.2007[227]. The scheme has a total budget of 600 k€ and natural persons that did a respective investment after 01.01.2019 are eligible to apply. There are four available categories for support, either for an installation of a water heating system or for the solar collectors. It is estimated that approximately 1,800 applications will be funded.

To support and enhance the above initiative, another support scheme, called Energy Audit Reports (EAR), was announced in June 2019[228] to provide incentives through financial support for the service sector called EAR. The EAR instrument will help the investors to identify the optimum measures and projects to be taken to achieve the highest economic benefit from such investments. The above scheme is eligible only for small and medium enterprises (SMEs), with a total budget available of 200,000 Euros. The SMEs that will participate in the above scheme, are eligible up to 2,000 Euros grant with 30% Funding rate.

Pilot actions should be also supported under the next period but under a specific market strategy that would foresee and anticipate the replication of these interventions and/or the uptake of various market mechanisms. In addition, the Fund has been subsidising various RES and Energy Efficiency measures from the year 2004 till today.

Table 43 summarises the latest incentives for Cyprus, while in the NECP submitted[229] for the period 2021-2030, there are more available future policies and measures, like the change in energy taxation, that can affect the energy consumption and thus promote other less energy intensive technologies.

[227] *https://www.resecfund.org.cy/sxedio1 (in Greek)*

[228] *http://www.mcit.gov.cy/mcit/EnergySe.nsf/All/C7A0AE3BCBC17758C225840E002DD701?OpenDocument*

[229] *https://energy.ec.europa.eu/system/files/2020-01/cy_final_necp_main_en_0.pdf*

Scheme name	Incentive on CAPEX	Incentive on OPEX	Other incentive	Existing (Y/N)	Start. date	Access conditions
Fund of Funds			Low interest loans	N	2020-2021	Considerable energy saving potential
Energy Audit Reports			30% Grant on audit to identify largest energy saving	Y	2019	SMEs
Change in Energy Taxation			Policy reform	N	2021	N/A

Table 43: List of CSP/CST incentives for Cyprus

Moreover, in an attempt to map the directions CST and CSP technologies may take at the national level, the following areas are identified as suitable for integration with solar thermal processes:

- *STE for large residential complexes and hotels:* The tourism industry plays a very significant role in the economy of Cyprus, despite the hit it has taken due to the Covid-19 pandemic. Flat plate and evacuated tube collector proliferation is widespread, but topics of investigations could include higher temperatures for domestic hot water use, and the usage of SHIP for washing, drying and sterilising of linens.
- *Non-metallic minerals:* Two main industries fall under these categories, which are also major energy consumers: Cement production and ceramics. Both are major energy consumers, but rely on their own petcoke and oil burners to fuel their operations. A thorough investigation (perhaps with the inclusion of reps from these companies) is worth considering. The temperatures of the operations however are usually high, and the appropriateness of SHIP technologies needs to be investigated.
- *Metallic minerals, mining and quarrying*: This category contains one of the known SHIP applications in Cyprus, in the facilities of Hellenic Copper Mines Ltd. Other mining companies operate on the island, as well as a few quarries. Expansion to these industries is a realistic prospect.
- *Food & beverages industry*: The Food sector in Cyprus is dominated by food packaging and retail companies, plus some processing, preservation, and pasteurisation of foodstuffs, mainly dairy. There is already one application, but this is an area of economic activity which is very active around the world, and new projects are added all the time. Especially in the dairy, water purification and juice packaging sector, there are potential applications in pasteurisation and sterilisation that are applicable to Cypriot industries. In addition, washing, cleaning

and tempering could link the beverages industry (mostly bottling in Cyprus) with SHIP.

- *Chemical and Pharmaceutical:* Two medium-sized industries (Remedica and Medochemie) operate in Cyprus that are manufacturing generic medication and supplying the local and regional markets. The processes the industries use utilise heat in the 100-170°C range and should be approached and explored for the integration of industrial heat in their operations.

10.3.1.4 Stakeholders

In Cyprus the value chain of CST technology is covered by the research, industry and policy stakeholders listed below:

- The Cyprus Institute (CyI, coordinator).
- RIF.
- Cyprus Technical Chamber.
- Applied Energy Laboratory/Energy Service of the Ministry of Commerce, Industry and Tourism.
- University of Cyprus.
- Cyprus Technical University.
- Cyprus Organisation for Standardisation.
- Cyprus Energy Agency.
- Cyprus Employers and Industrialists Federation & Cyprus Union of Solar Thermal Industrialists (EBHEK).

In addition, the CST research stakeholders in Cyprus has a partnership with the Cyprus Chamber of Commerce and Industry. The Cyprus Employers and Industrialists Federation is the umbrella organisation for all energy associations in Cyprus including EBHEK and Cyprus Association of Renewable Energy Enterprises.

10.3.2 Key findings

There are several future directions for CSP which could be considered at a national level:

- *Further development of research infrastructures (RIs):* Development of RIs should help to further expand knowledge in the field and into technological advancements which will render CSP a more attractive technology for Cyprus, a country with high solar irradiance. RIs could further explore the concept of high temperature CSP units, and of thermal and/or electric storage which is typically associated with CSP/CST applications. A prime application would be the testing of experimental facilities of smaller scale: Small-scale experimental infrastructures could be developed for testing novel applications of CSP and integration of renewables and/or storage units. This should also help into shaping regional networks and strengthen cooperation. Also, solar thermal storage could also be exploited when combined with chillers to supply cooling in several sectors, e.g., hotels. Cooling is an area which would have several benefits in Cyprus considering the high temperatures. Furthermore, RIs could be used to explore the synergies between CSP and hydrogen. Cyprus has a significant potential of renewable gases and most notably renewable hydrogen. For example, during periods of high penetration of energy from renewables, excess energy could be stored in the form of hydrogen in fuel cells, a fuel that can be used in transport, as well as in industrial and even domestic applications. Hydrogen could become a solution for the long-term (seasonal) flexibility of the energy system and can be developed in parallel with CSP which can provide short-term flexibility.

- *Promotion of District Energy Systems:* It is well established that the electricity market will change in the next few years, with the promotion of ***energy communities*** and the concept of ***prosumers***. CSP could be appropriate as a small-scale district energy system, which could be used to supply electricity at a local level. PROTEAS research facility is aiming towards this direction, although currently has a very small capacity and is at a relatively remote location. Nevertheless, this kind of concept would be of particular interest for an island like Cyprus.
- *Support services to the CSP/CST industry*: A unit should be formed which will support the CSP/CST industry and offer services to potential investors which might be interested in investing in the field. Several investors might be prejudiced due to the relatively high costs of these technologies; however, they are not properly informed. Therefore, a unit formed with the support of the government could offer financial and technical advice and help promote the development of CSP/CST.
- *More funds for networking projects:* To further promote and develop the technologies of CSP/CST networking projects should be supported. This will help to enhance knowledge and get know-how from leading EU countries in the field. Also, cooperation with countries in the area with interest in the CST/CSP might also lead to projects of common interest.

10.4 Overview of the context in Switzerland

10.4.1 R&I landscape

This section presents the main outcome of the background research and the analysis of the information and opinions collected from the SFOE, contacted by DLR. It is divided into the financial framework, the ongoing activities of Swiss R&I entities and the cooperation both at national and international level that has an impact into the focus of research and funding.

10.4.1.1 Switzerland' R&I energy support programmes

In Switzerland, approximately 8.3 million Euros of public funding is used for RTD in the field of Solar thermal power and high-temp. applications (International Energy Agency (IEA) classification 313, figures for 2020). About half of this funding is competitive via project grants, with funding through EU projects taking up a large share. In Switzerland, project funding in this field is mostly provided by the Swiss National Science Foundation and the energy research funds of the SFOE.

The SFOE runs a dedicated RTD programme to promote application-oriented research in this area (see research concept for the period 2021 to 2024[230]) and can also support pilot and demonstration projects in Switzerland. One of the priority activities supported by the SFOE is solar thermal chemistry (the process of producing hydrogen and synthesis gas – solar fuels). Here the focus is primarily on practical implementation in large output ranges. Another of the SFOE's priorities concerns the development of innovative elements for STE and process heat production: receiver systems with new thermal fluids, new high temperature storage systems, active reflector cleaning systems, combination of concentrated solar energy and process heat.

10.4.1.2 Existing R&I activities (list of current projects and initiatives) related to CST technology

The key data of R&I projects in Switzerland related to the CST technologies are shown in Table 44.

[230] *www.energy-research.ch*

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Swiss Industrial Partners	Swiss R&D Partners
N	Receiver for CSP	REVERSO	ETHZ	2021-2025	---	ETH Zurich, Institute of Fluid Dynamics
N	Solar Receiver for the production of solar fuels from H2O, CO2, and CH4	Fuelrec II	SUPSI	2021-2024	Synhelion	SUPSI, University of Applied Sciences and Arts of Southern Switzerland
N	Advanced thermocline concepts for thermal energy storage for CSP	NEWCLINE	OST/SPF	2020-2024	---	University of Applied Sciences of Eastern Switzerland OST, SPF Institute for Solar Technology
N	Reactor system for the production of solar fuels from H2O, CO2, and CH4	HYBREC	ETHZ	2019-2022	Synhelion	ETH Zurich, PREC
N	Modelling of Absorbing Gas	ReceiverSIM	SUPSI	2017-2018	Synhelion	SUPSI, University of Applied Sciences and Arts of

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Swiss Industrial Partners	Swiss R&D Partners
	Receivers for Solar Applications					Southern Switzerland
N	Concentrated photoelectrochemical fuel generation: scale-up, on-sun testing, and flexibilzation	ConPEC	EPFL	2017-2020	SoHHytec	EPFL, Laboratory of Renewable Energy Science and Engineering
N	Reduction of CO2 emissions through integration of scalable and cost-effective modular solar pro-cess heat units	BILLY SOLAR	OST/SPF	2019-2021	---	University of Applied Sciences of Eastern Switzerland OST, SPF Institute for Solar Technology
N	Concentrator for solar thermal power generation	DAFL	HES-SO	2022-2023	---	HES-SO
N	High-Temperature Thermal Energy	HiT-TES	Empa	2021-2023	Synhelion	Empa

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Swiss Industrial Partners	Swiss R&D Partners
	Storage for Solar Fuel Production					
N	Solar Dish-Reactor Technology for the Production of Liquid Transportation Fuels from H2O and CO2	SOLIFUEL	ETHZ	2015-2021	Synhelion	ETHZ
EU	Turning up renewable solar heat and power for efficient green hydrogen production	PROMETEO	ENEA	2021-2024	SOLIDPOWER (Switzerland)	EPFL
EU	Solar Facilities for the European Research Area - Third Phase	SFERA-III	CIEMAT	2019-2022	---	ETHZ
EU	Supercritical CARbon dioxide/Alternative fluids Blends for	SCARABEUS	POLITECNICO DI MILANO	2019-2023	---	Quantis Sàrl

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Swiss Industrial Partners	Swiss R&D Partners
	Efficiency Upgrade of Solar power plants					
EU	Joint programming actions to foster innovative CSP solutions	CSP ERANET	AGENEX	2019-2024	---	DETEC
EU	Industrial Cooling through Hybrid system based on Solar Heat	HyCool	VEOLIA	2018-2022	GIVAUDAN SUISSE SA	Empa
EU	Towards Efficient Production of Sustainable Solar Fuels	ECLIPSE	ETHZ	2019-2021	---	ETHZ
EU	Solar Energy for Carbon-Free Liquid Fuel	Sun-To-X	Toyota	2020-2024	---	EPFL
EU	Thermochemical HYDROgen production in a	HYDROSOL-beyond	ETHNIKO	2019-2023	ENGICER SA	SUPSI

National (N) or European (EU)	Project Name	Acronym	Coordinator	Years of execution	Swiss Industrial Partners	Swiss R&D Partners
	SOLar structured reactor:facing the challenges and beyond					

Table 44: Relevant R&D projects with involvement of Swiss stakeholders

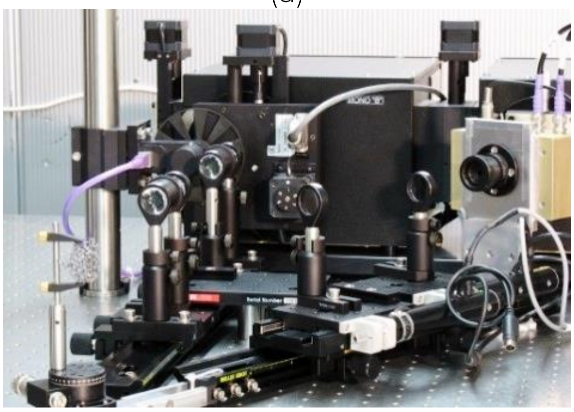
With respect to Swiss infrastructure, the Eidgenoessische Technische Hochschule Zuerich (ETHZ) is the main research center dedicated to CST.

ETH Zurich is a university for science and technology that dates back to the year 1855, when the founders of modern-day Switzerland created it as a centre of innovation and knowledge. Situated in the heart of Europe, it has a reputation for forging connections all over the world. A vibrant centre for education and R&D, at ETH Zurich researchers are in a climate which inspires top performance. The universities policies on research are founded on intellectual honesty and scientific integrity.

The Professorship of Renewable Energy Carriers (PREC)[231] is committed to excellence in research and education. It performs pioneering R&D projects in emerging fields of renewable energy engineering, operates state-of-the-art experimental laboratories, with expertise in CSP technologies. The PREC lab has approximately 30 research staff working on a range of R&D projects in the field of CSP. The infrastructure is equipped with a high flux solar simulator for testing reactors and receivers used in CSP technologies, as well as supporting characterisation techniques such as flux measurements and in-situ gas analysis (Figure 67). Additionally, there is a materials chemistry laboratory, with state of the art facilities for characterising materials, and the thermodynamics and kinetics of multi-phase reactions.

(a)

(b)



(c)

(d)

[231] *https://ethz.ch/content/dam/ethz/special-interest/mavt/energy-technology/renewable-energy-carriers-dam/documents/Research/PREC Brochure 2020.pdf*

(e)

Figure 67: PREC infrastructure: (a) High-Flux Solar Simulator, (b) Chemistry Lab, (c) Optical Laboratory, (d) Thermal Laboratory, and (e) Solar Concentrator/Reactor Facility

10.4.1.3 National and international cooperation

Due to the limited number of actors, there is close linkage at the national level between different research institutions and industry actors.

On an international level Switzerland is a long-standing member of SolarPACES (Solar Power and Chemical Energy Systems), the international cooperative network in the field of CSP established as Technology Collaboration Programme under the framework of the IEA. In SolarPACES, Switzerland is leading for many years the working group (task) on Solar Chemistry Research, aiming to develop and optimise solar-driven thermochemical processes. In a joint task with the IEA Photovoltaic Power Systems Programme, Switzerland has the co-lead in the area of solar resource assessment, and in a joint task with the IEA Solar Heating and Cooling Programme the co-lead for the topic of Solar Heat Integration in Industrial Processes.

Through the instrument of European Research Area Networks (ERA-NET), the SFOE was participating in several joint calls within the SOLAR- and CSP-ERA-NET, in which subsequent projects in this framework with Swiss participation have been developed.

Swiss actors are also involved in the joint programme EERA on CSP, established with the launch of the SET Plan, that supports industry in the field of CSP and clusters European RTD activities.

As part of the European projects “Solar Facilities for the European Research Area” SFERA 1 to 3, Swiss instates offer access to infrastructure. In the European Alliance of European Laboratories for Research and Technology on Solar Concentrating Systems, Swiss actors are involved in training activities such as doctoral colloquia.

There is also close international cooperation in the industrial sector, especially around the Swiss company Synhelion[232], which is one of the leading players in the field of solar fuels.

10.4.2 Key findings

- Because in Switzerland there is no potential for the use of CSP technology (with the exception of solar process heat), research concerns the development of innovative solutions mostly for exportable technologies.
- Another priority concerns the use of systems for generating process heat in Switzerland based on various pilot facilities with scientific support. Here, detailed studies are being carried out. The objective is to obtain fundamental data regarding both the technological and the economic potential of systems of this type in Switzerland.

[232] *https://synhelion.com/*

10.5 Glossary

CSP	Concentrated Solar Power
CST	Concentrated Solar Technologies
CyI	Cyprus Institute
EAR	Energy Audit Reports
EBHEK	Cyprus Union of Solar Thermal Industrialists
EIB	European Investment Bank
ERA-NET	European Research Area Networks
ESCOs	Energy Service Companies
ESIF	European Structural and Investment Funds
ETHZ	Eidgenoessische Technische Hochschule Zuerich
H2020	Horizon 2020
IEA	International Energy Agency
NECP	National Energy and Climate Plan
PREC	Professorship of Renewable Energy Carriers
PROTEAS	Platform for Research, Observation, and Technological Applications in Solar Energy
PV	Photovoltaic
R&D	Research and Development
R&I	Research and Innovation
RES	Renewable Energy Sources
RIF	Research and Innovation Foundation
RIs	Research Infrastructures
RTD	Research Technology and Development
SET Plan	Strategic Energy Technology Plan
SFOE	Swiss Federal Office of Energy
SHIP	Solar Heat for Industrial Purposes
SMEs	Small and medium enterprises
SolarPACES	Solar Power and Chemical Energy Systems
STE	Solar Thermal Electricity

10.6 Appendices

10.6.1 References

Cyprus – R&I

Cyprus' Integrated NECP [online]

Ministry of Energy, Commerce and Industry [online]

RES and Energy Conservation Fund [online]

SFERA-III Concept Note for Cyprus

Switzerland – R&I

PREC brochure [online]

Swiss Federal Office of Energy research concept 2021 to 2024 [online]

APPENDICES

Meeting guidelines

Introduction

- Presentation of ESTELA
- Presentation of HORIZON-STE, main purposes, methodology (deepening of our understanding of the national perspective and how / consultation within the CSP sector and report where Country could receive support from the CSP industry), national and international targets
- Introduction of the Interviewee and their positions
- Interview, following the Interview guidelines, and discussion

Interview guidelines

1. General perspectives of energy policy in the Country (10')

1.1. General targets and objectives

- *Global energy policy drivers (economic, environmental, social, geopolitical)*
- *Potential contingencies, bottlenecks*
- *Resulting priorities*
- *Latest forecasts / prospects resp. perceived opportunities for the Country's economy*
- *Regional differentiation (get map)*

1.2. How could the regulatory framework for electricity and gas evolve in the Country in the mid-term? *[e.g.: do you perceive the regulatory environment as favourable or not for achieving the objectives set by the government? What would you identify as successes and limitations of the current regulation so far?]*

1.3. Evolution of demand and consumption? *[e.g.: What are the current challenges in the energy system? What do forecasts look like on the short / mid and long-term? ...]*

1.4. Evolution of capacity connections? *[e.g.: what is the current use of the infrastructures? What are the development plans? ...]*

1.5. Status of interconnections? *[e.g.: what is the current status of interconnections with other Member States? Are any new interconnections planned with neighbouring countries? Bulk energy purchases? ...]*

1.6. Status of the draft regulation on energy storage? *[e.g.: Is any specific technology favoured in terms of energy storage? ...]*

1.7. Support mechanisms for renewable energies?

- *Current status?*
- *Any foreseen adjustments of these mechanisms? What could trigger such changes?*
- *What is the status of the (subsidised) long-term loans for renewable energy projects?*
- *What is the status of the renewable energy cooperatives? Exclusively intended for the PV sector? …]*

1.8. According to you, what would be the necessary conditions for an innovative technology such as CSP/CST to really take off in the Country? [*e.g.: Do you consider receiving enough support for developing your business? What are the signals which motivate you to take risks for business? …*]

2. Particular aspects of interest for Interviewee regarding RES and CSP (20')

2.1. In general, how would you evaluate the framework for developing innovative technologies/businesses in the Country? [e.g.: What is very helpful? What is more of a challenge? What would you change? Do you think sometimes that it is easier to develop project in another country? …]

2.2. Are you currently / Have you been involved in projects related to CSP/CST (in the Country or abroad)? If yes, how many? [e.g.: Do you also collaborate with foreign companies? Which benefit do you see in that? Would you say that the Country's business framework favours collaborations between local and foreign companies? …]

2.3. In your view, which actors are of capital importance to favour the development of a new technology? [e.g.: Policymakers? The regulatory authority? Financing bodies? Foreign companies? Do you have specific expectations on each of these actors?]

2.4. How do you see the CSP/CST market in the Country in the next 5-10 years? [e.g.: Do you see any development opportunities? What would be your ideal scenario for the development of the technology? Are you interested in participating in research/FOAK projects?]

2.5. Perceived challenges and opportunities for the future development of the Country's electricity market? [e.g.: is there a need for market opening? Ideally, what would favour a bigger mix of electricity providers? What could be the potential changes affecting the schemes for funding renewables …]

2.6. Planned implementation / procurement of solar generation? [*e.g.: Would the installation of CSP plants be considered…*]

2.7. Considering the potential of CSP? [e.g.: Do you see any regulatory barriers that would prevent CSP power plants from being included in the electricity market system? If so, how would you consider that this could be fixed?]

2.8. Manageable RES and storage option? [*e.g.: Which perception do you have of energy storage? …*]

2.9. Possibility to increase capacity and stability through CSP? [*e.g.: Would the use of locally produced energy be a strong argument in the extension of the grid? What would be the installation requirements? Unlicensed production? …*]

2.10. Hybridisation of conventional power plants? [*e.g.: Could current conventional power plants be hybridised with CSP? …*]