



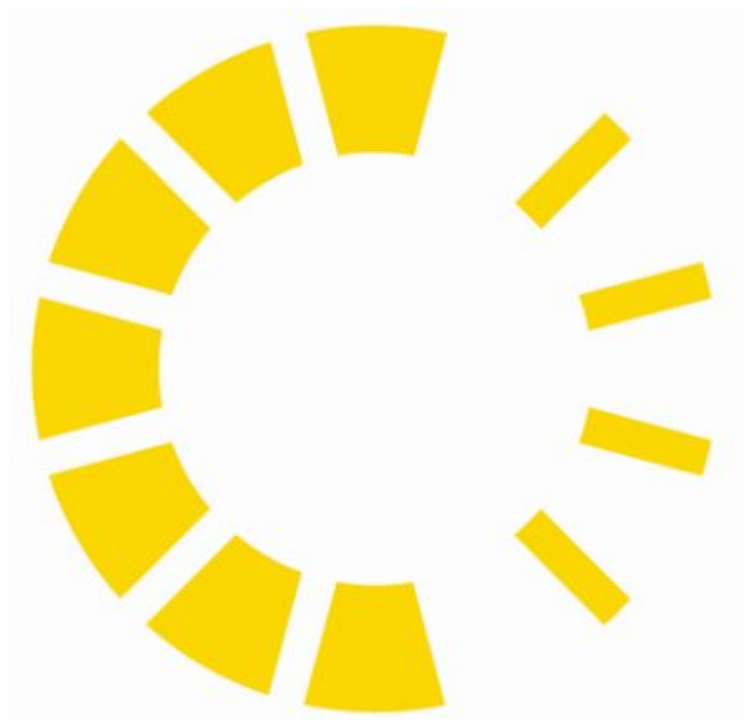
Synthesis of key issues affecting CSP development in Europe

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ABOUT THE PROJECT

In the light of the EU 2030 Climate and Energy framework, *MUSTEC- Market uptake of Solar Thermal Electricity through Cooperation* aims to explore and propose concrete solutions to overcome the various factors that hinder the *deployment* of concentrated solar power (CSP) projects in Southern Europe capable of supplying renewable electricity on demand to Central and Northern European countries. To do so, the project will analyze the *drivers and barriers* to CSP deployment and renewable energy (RE) cooperation in Europe, identify future CSP *cooperation opportunities* and will propose a set of concrete *measures* to *unlock the existing potential*. To achieve these objectives, MUSTEC will build on the experience and knowledge generated around the cooperation mechanisms and CSP industry developments building on concrete CSP *case studies*. Thereby we will consider the present and future European energy market design and policies as well as the value of CSP at electricity markets and related economic and environmental benefits. In this respect, MUSTEC combines a dedicated, comprehensive and multi-disciplinary analysis of past, present and future CSP cooperation opportunities with a constant *engagement* and *consultation* with *policy makers* and *market participants*. This will be achieved through an intense and continuous *stakeholder dialogue* and by establishing a tailor-made *knowledge sharing network*.

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1 INTRODUCTION

1.1 Background

The transition of the European energy system towards a more sustainable energy supply, and in particular the decarbonisation of the electricity sector through the deployment of renewable energy technologies, is a key element of the European climate change strategy. For the time horizon 2020-2030, the European Commission has defined an EU-wide 2030 target of 32% for the share of renewable energies in the gross final energy consumption. However, in contrast to the regulatory framework up to 2020, there are no more binding targets on Member State level. This absence of mandatory renewable energy targets on national level emphasizes the relevance of coordination and collaborative approaches to reach the envisaged renewable energy share on European level. Collaborative efforts could play an important role in achieving the European energy transition at lower cost than purely national approaches, as renewable sources could be exploited at locations that require low support costs by offering high potential thus leading to lower overall system costs.

With high shares of renewable energy, electricity system flexibility gains importance. Energy storage and dispatchable electricity generation technologies can help to balance the in-feed of variable renewable energy sources (RES). Concentrated Solar Power (CSP), as a dispatchable renewable energy technology combined with thermal energy storage, could contribute to the deep decarbonisation of the European Energy system by providing sustainable electricity and adding to system flexibility. Due to the still comparatively high electricity generation costs compared to other renewable energy technologies such as PV or onshore wind turbines, CSP could particularly benefit from collaborative efforts of EU Member States sharing the costs and the benefits of CSP projects.

However, even though RES cooperation mechanisms have been introduced by the European Commission already in 2009 in order to allow the EU Member States to reach their binding 2020 renewable energy target shares with joint efforts and potentially at lower costs, they have hardly been used and never involved any CSP projects.

Against this background, the MUSTEC project has the objective to analyze the framework conditions for CSP deployment in Europe with an integrated view on the multitude of aspects that may represent barriers or drivers for the collaborative development of CSP projects. Areas that are particularly relevant in this regard encompass: Issues relating to the political feasibility and social acceptance of potential CSP cooperation projects, the determinants that affected the non-use of cooperation mechanism in the past and the potential future impact of the post-2020 political and regulatory framework and importantly, techno-economic parameters, such as technology cost development, available cross border transmission capacities or different market design options.

1.2 Objective and structure of this report

Within the MUSTEC project, this report aims to consolidate the findings of the previous work packages (as far as they are available at the point of writing this report) and to summarize and systematize the major lessons learnt on CSP development and RES cooperation in Europe. Rather than generating new content, the report tries to synthesize and highlight the most relevant barriers and drivers for collaborative CSP deployment identified in the frame of the MUSTEC project so far, which are relevant for the possibilities for potential CSP cooperation projects in the future.

This summary of major barriers and crucial requirements for CSP cooperation projects further serves as a basis for the development of a roadmap for collaborative CSP deployment in Europe (MUSTEC deliverable 10.2) and the derivation of recommendations on how policy makers on European and national level could address the identified issues and enable CSP cooperation by creating favorable framework conditions (Action Plan, MUSTEC deliverable 10.3).

The report is structured as follows:

The following chapter 2 summarizes the main issues affecting collaborative CSP development in Europe that have been identified in the previous work packages of the MUSTEC project. Thereby, section 2.1 focuses on the most relevant aspects relating to techno-economic parameters and the market environment for CSP, such as the technology cost development and other factors that influence the competitiveness of CSP in the European electricity market. Section 2.2 elaborates on the most relevant barriers and the requirements related to the regulatory and political framework for the collaborative development of CSP in the EU. Section 2.3 summarizes the findings on social acceptance and the views of different stakeholders on potential CSP cooperation projects. Each section provides a brief summary of the respective topic, highlights the key issues and crucial requirements and provides references to the underlying detailed reports that have been generated in the frame of the MUSTEC project.

Chapter 3 presents the preliminary conclusions.

2 SUMMARY OF MAIN ISSUES AFFECTING COLLABORATIVE CSP DEVELOPMENT IN EUROPE

2.1 Techno-economic parameters and market environment

The market environment for CSP projects in Europe and the future development of techno-economic parameters of CSP projects define to which extent the technology will be competitive in the European electricity market. Within the MUSTEC project, an in-depth analysis across several work packages investigated the various factors that play a role for the competitiveness of CSP in the context of European RES cooperation. This section takes a closer look at different techno-economic parameters and the existing market environment for CSP projects. Based on the extensive research done in the frame of the MUSTEC project, we are going to answer the following questions:

- Which CSP technologies exist and which technology trends can be observed?
- What are the cost trends for different CSP technologies and which parameters have an impact on the costs?
- Which market structure enables CSP development?

In order to answer these questions, we first focus on the technology and cost development of CSP (section 2.1.1). The following section 2.1.2 provides an overview over the market structure and related barriers and drivers for CSP. At the end of the subchapter, the key issues and crucial requirements are summarized.

2.1.1 Technology and cost development

In the following chapter, we will focus on the technology as well as the cost development of CSP in the recent years. First, we will show the development for different CSP technologies and determine trends. Second, we will look at the cost development for these technologies for the past years.

2.1.1.1 CSP-Technology development

Several technology setups can be grouped under the category Concentrated Solar Power (CSP) stations: Solar towers, parabolic trough, dish Sterling and linear Fresnel power plants. Among these CSP technology types, parabolic trough is the dominant technology option with 67 of the 78 existing CSP stations, as well as 11 of the 20 CSP stations under construction worldwide. Therefore, parabolic troughs have been and remain the dominant CSP technology choice across the world. In Figure 1 the technology choice for CSP stations, which are becoming operational are shown for the years 1984 to 2020. The figure shows that for the past years, there is a trend towards solar towers, but so far, the expectation that towers would take over as the dominant technology has not been met. However, it is notable that most of the spectacular announced projects, such as Aurora and ongoing developments in Chile, are towers, and that these bid at yet unprecedented low prices. It should be noted, though, that several of these projects have not been realized. Based on these observations

it is possible that we will witness a breakthrough of the solar tower in the future, but so far, troughs remain the dominant CSP technology (Lilliestam 2018).

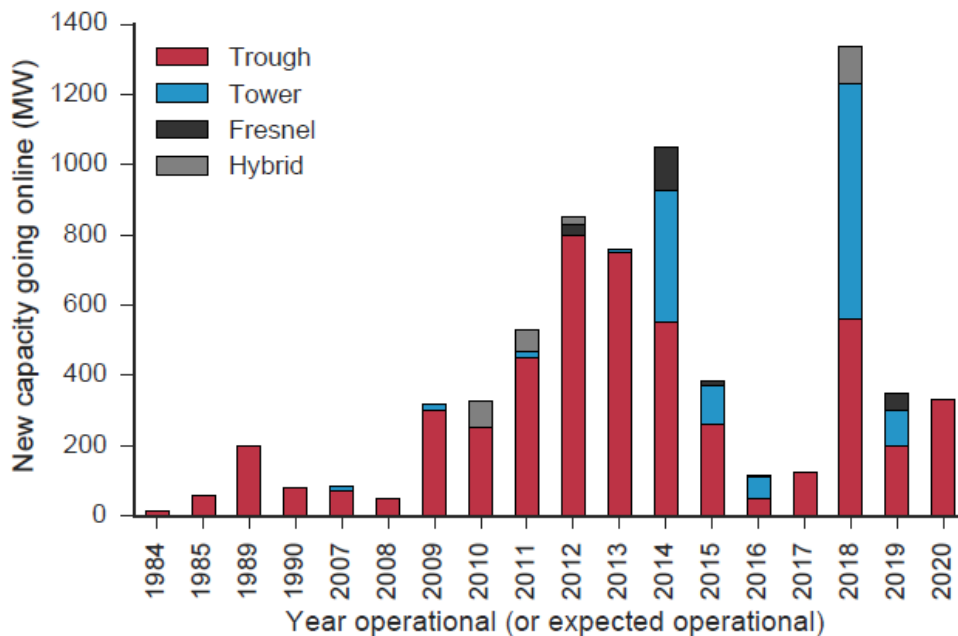


Figure 1: Technology choice for CSP stations (excluding hybrids) by the year they are becoming operational (or expected to become operational) (Lilliestam 2018)

Furthermore, there is a clear trend towards larger thermal storages and higher load factors. Whereas CSP stations without storage were the by far most common configuration pre-2015, there were only two stations without storage under construction in 2018 (Ashalim B, Israel; Abhijeet, India) of which only one (Ashalim) has been finished and one (Abhijeet) got cancelled. In addition, there is a strong trend towards a more diverse set of technology configurations. (Lilliestam 2018)

The size of the solar field and the storage size have an important impact on the ability of the CSP plant to cover demand most continuously. This is demonstrated by a case study, which analyzed a hypothetical 200 MW_{el} CSP plant with an 11 hours storage system in Spain (Schöniger, F., Resch, G. 2019). The modelling was based on the full Spanish electricity system of the year 2018 and in order to assess how the CSP plant could operate under the current market condition and in possible future market development. Exemplary for the focal country Spain, this analysis considered variations of different framework factors such as CO₂ prices, price developments of fossil fuels and the deployment of other renewable energy technologies. The resulting market values of CSP, i.e. the average revenues per MWh that can be generated on the electricity market, are shown in Figure 2 (Schöniger, F., Resch, G. 2019)

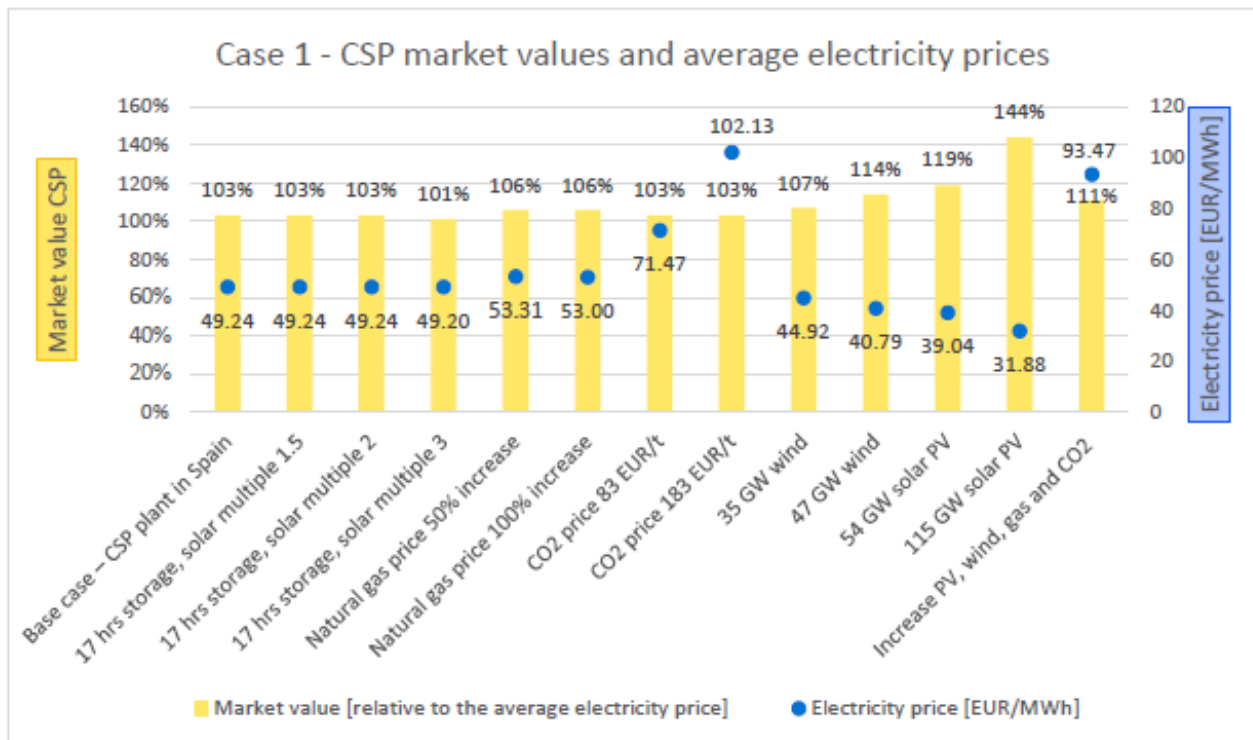


Figure 2: Summary of the results for a CSP plant as system contributor in Spain: Comparison of market values for CSP in relation to the electricity price under variations of different framework factors (Schöniger, F., Resch, G. 2019)

The case study concludes that increasing the storage size in the current market setting barely changes the operational profile of the CSP plant but becomes increasingly important with rising shares of fluctuating renewable sources like wind and PV in the system. Provision of 24 hours of continuous generation of the CSP plant during the summer time is realized when scaling up the solar field in accordance with the storage. In a market setting, where in parallel to increased shares of PV and wind, also CO₂ and natural gas prices are rising, a high market value of CSP and high average electricity prices lead to high revenue levels for CSP. In a possible future electricity system representing these features, CSP could play out its main operational advantages - dispatchable, renewable, and CO₂-free generation of electricity.

A systematic analysis of CSP plant configurations potentially suitable for European cooperation projects performed by Souza (2018) showed that the future types of plants constructed would be based on the specific configurations that define an operational profile, which comes in response to the individual off-taker's needs, rather than being a standardized product or being dictated by what was developed historically. Generally, larger storage capacities (8-15 hours) and hybridization, with both fuel-based back up or PV, seem to be very promising and yielding attractive performances and low costs already today (e.g. the PV/CSP hybrid projects Noor I in Dubai or Noor Midelt in Morocco).

2.1.1.2 CSP-cost development

Analyses of past and present CSP projects have shown that the levelized cost of electricity (LCOE) for CSP are still higher than that of wind and PV. By now, costs for ongoing CSP projects reach 0.12 USD/kWh on average. In Figure 3 the LCOE of all CSP stations, existing and under construction, are shown. The trend for the LCOE of CSP shows a clear decrease during the last years. For parabolic trough stations, costs are declining fast, but even faster for solar towers. Recent solar tower plants are already cheaper than solar troughs (Lilliestam 2018).

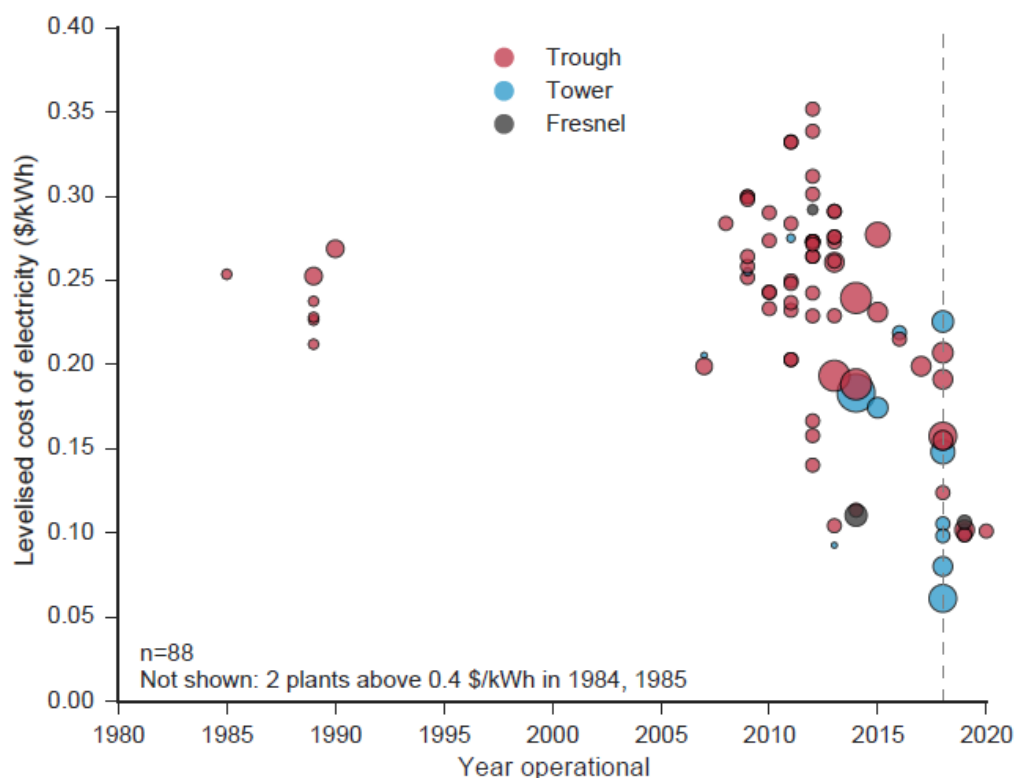


Figure 3: Analysis of the LCOE of all existing CSP stations (past and present) and those under construction by technology type (excl. hybrids) (Lilliestam 2018)

The LCOE of CSP plants with larger storage and, therefore, a higher level of dispatchability are lower. Therefore, the LCOE rather decreases with storage size (Lilliestam 2018). Another report by (Papadopoulou A. et al. 2019b) analysed the impact of different parameters on the LCOE for CSP with storage and conducted a sensitivity analysis to show which parameters have the highest impact on the generation cost of CSP (see Figure 4). As can be derived from Figure 4, the parameter most significantly affecting the LCOE is the investment cost. The parameter, which has the second most significant influence on the LCOE is the discount rate applied. Variable O&M costs create a 6%

variation on the LCOE value, and are therefore on third place regarding the influence on the LCOE value. Fixed O&M costs have a negligible impact on the LCOE. Finally, the LCOE calculated for an average value at all costs is 0.1429€/kWh as can be derived from Figure 4. (Papadopoulou A. et al. 2019b)

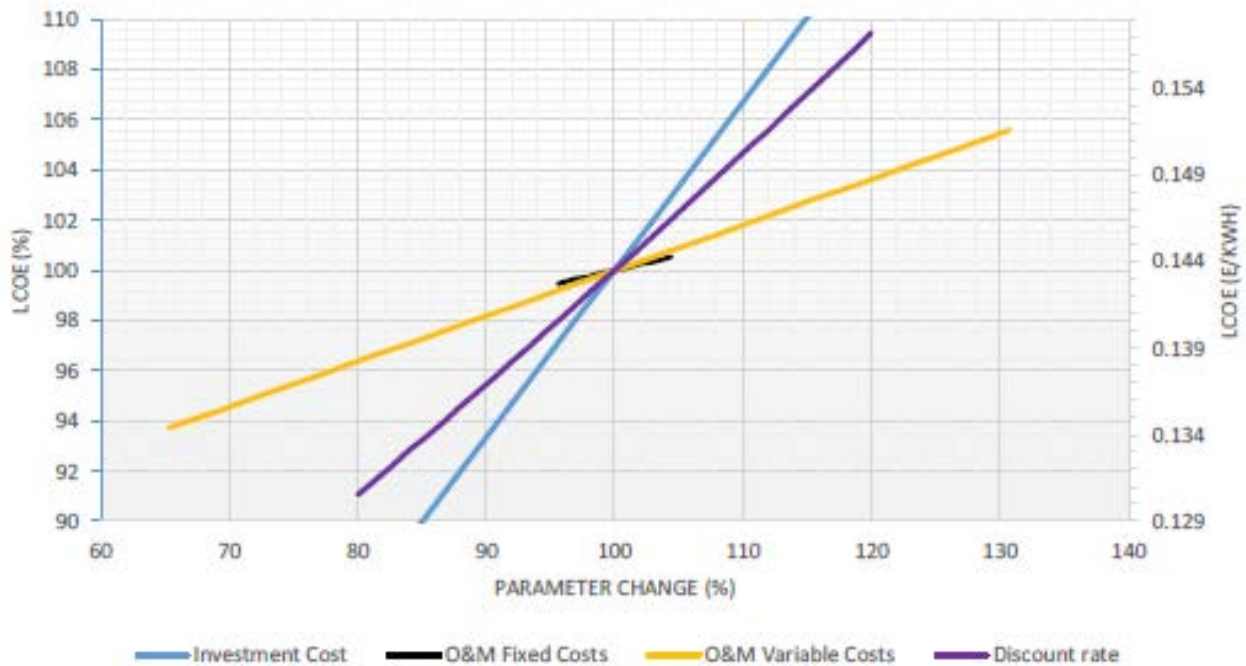


Figure 4: Sensitivity analysis for the influence of different cost parameters on the LCOE of CSP with storage (Papadopoulou A. et al. 2019b)

In order to further investigate which parameters enable the competitiveness of CSP plants in different electricity system setups, (Schöniger, F., Resch, G. 2019) analyzed various scenarios with a power system optimization model under the condition that a defined off-taker's demand profile has to be met in every hour of the year. Figure 5 summarizes the results of this analysis which compares different technology configurations and shows which role CSP could play in each of these scenarios.

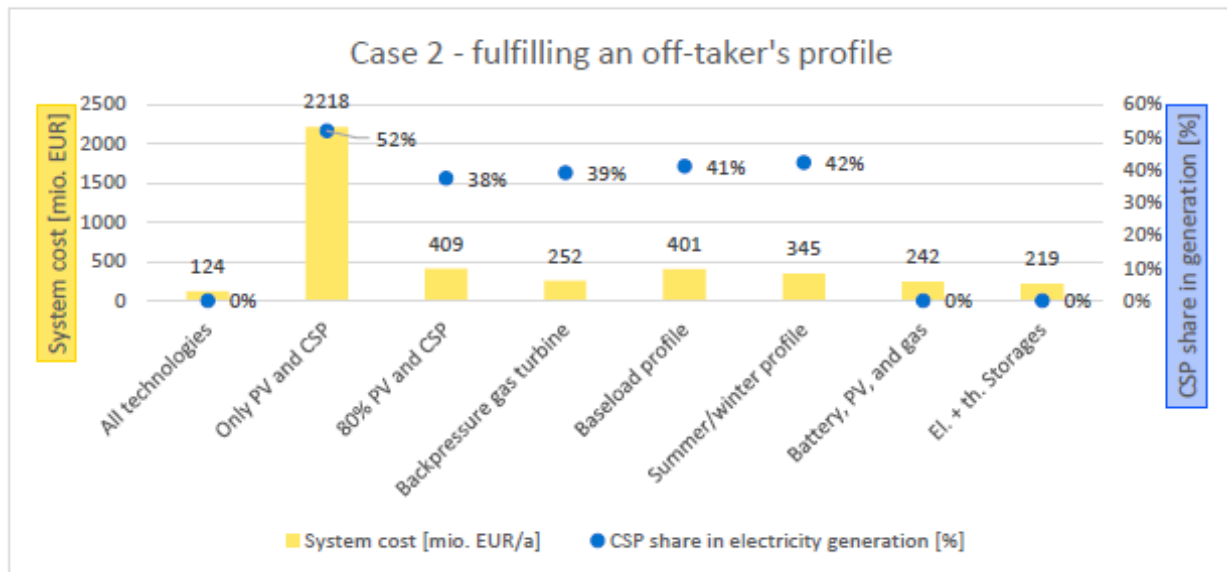


Figure 5: Comparison of different electricity system setups regarding the resulting system costs and the role of CSP in the electricity system. Case study for Spain while fulfilling a defined off-taker's demand profile. (Schöniger, F., Resch, G. 2019)

Based on the results, the cost optimized solution under current cost assumptions to fulfill the off-takers demand profile is a combination of natural gas and PV, i.e. overall system costs are the lowest in this case (124 Mio. €/a). Fulfilling the same off-takers profile only with CSP and PV leads to huge over capacities during the summer, since the low irradiation during the winter defines the unit size. In addition, this leads to the highest system costs of 2218 Mio. €/a. The demand during the winter period basically determines the size of the investment. (Schöniger, F., Resch, G. 2019)

Further, the model-based analyses by (Schöniger, F. et al 2020) stress the importance of carbon pricing for the competitiveness of CSP in the market and show that high carbon price levels are a crucial precondition but not a guarantee for CSP deployment (see Figure 6 and Figure 7). In general, the higher the CO₂ price, the higher the share of CSP in the system. However, based on the present technology cost, CSP is not competitive even with a CO₂ price of 200 €/t. Assuming drastic technology cost reductions, the share of CSP increases but both, cost reductions or a high CO₂ price alone, do not suffice to reach a CSP share in the system higher than 10%. The modelling results highlight that only if both factors are combined, CSP is able to play a significant role in the system and compete against other generation technologies. Assuming 50% cost reductions and a CO₂ price of 100 €/t, the resulting CSP share reaches 36%. The same result can be triggered by a cost reduction of 25% and a CO₂ price of 300€/t.

These findings emphasize that only a combination of effective carbon pricing and targeted support for CSP will lead to significant CSP deployment in the future.

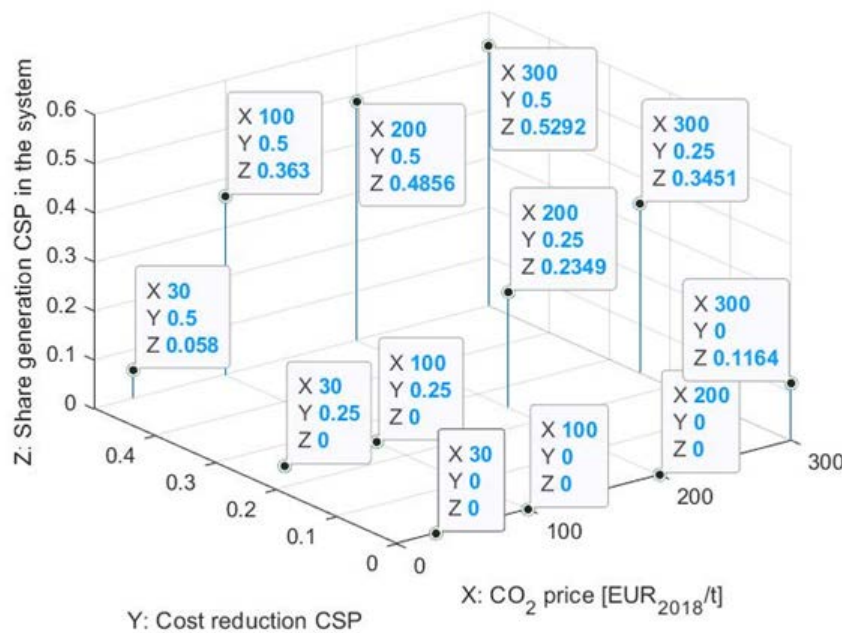


Figure 6 Impact of CSP technology cost reductions and CO₂ price on the share of CSP generation in a closed system based on the demand patterns of Spain. Demand is covered by the three technology options: CSP, PV, and natural gas. (Schöninger, F. et al 2020)

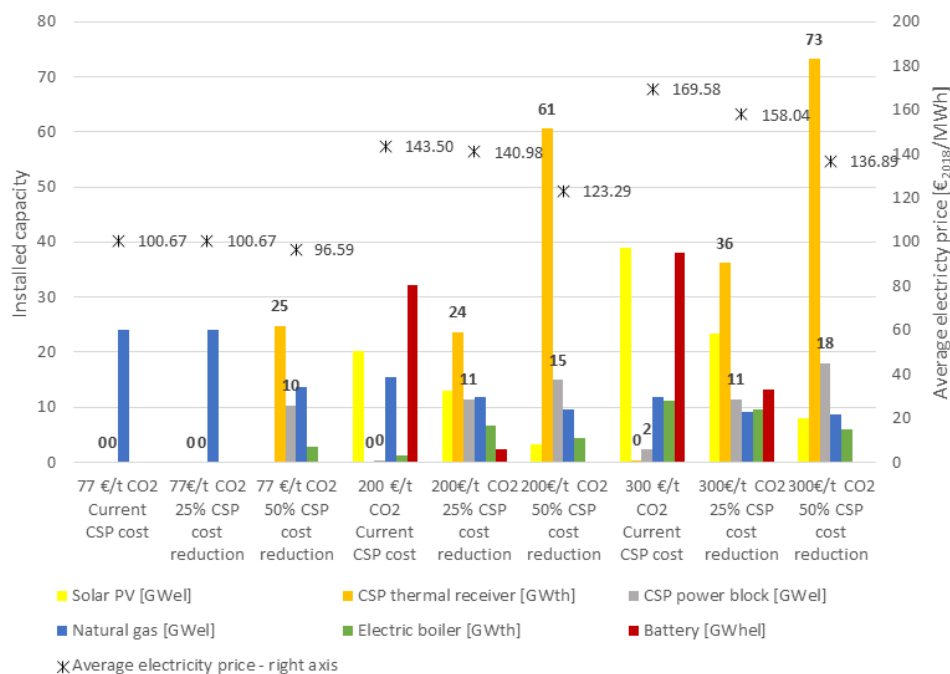


Figure 7 Results of investment and dispatch optimization for Spain 2030. The planned fluctuating renewable generation capacities hydropower, PV, and wind were given as exogenous input parameters. (Schöninger, F. et al 2020)

The above described quantitative modelling results are further supported by qualitative findings based on a stakeholder consultation by (Del Río et al. 2019) who found that the costs of CSP plants are considered as the major barrier for future CSP expansion. Furthermore, for importer countries, the cost of the CSP project is considered as the highest impact factor on the attractiveness of the project (Del Río et al. 2019).

2.1.2 Market structure and business models for CSP

This section focuses on parameters which influence the competitiveness of CSP in the electricity market and the business models and niches for the CSP industry. Figure 8 shows a variety of options for enhancing the flexibility of an electricity system with high shares of renewable energies. Six different types of innovations and their costs are compared. CSP technology options are not mentioned, but could be classified under flexible generation as well as under the storage category. There are several options for flexible generation and storage in the electricity system and the competitiveness of each option depends on the respective system setup. Nevertheless, as most likely a technological portfolio and a variety of innovative solutions for market design will be necessary to achieve the previously outlined ambitious decarbonisation goals, it is not unlikely that CSP will find its role (Welisch 2019).

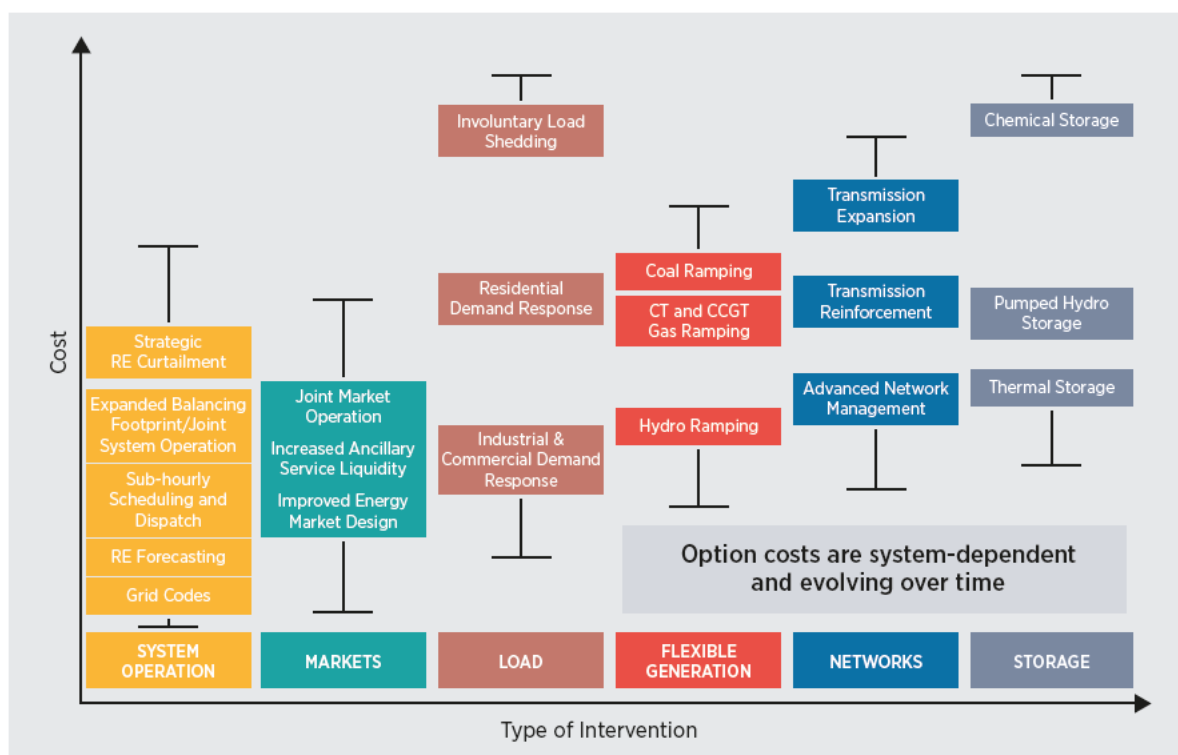


Figure 8: Comparison of technology options / interventions to enhance flexibility in a high-renewable energy system and their costs (Miller, M. 2015)

To make CSP deployment profitable, market designs that set the appropriate price signals and reflect the value of flexibility will be necessary. The main impediments today lie in the design of support policies and lacking transmission grid infrastructure, especially in between countries (Welisch 2019).

In recent years, **the CSP industry has been facing a transition**. Numerous new actors have entered the CSP market. Therefore, the CSP value chain becomes more robust and less dependent on single companies. Furthermore, new actors are likely to bring innovations in the market. However, it can also be observed that all experienced EPC (engineering, procurement and construction) and developer companies but two seem to have left the market. Previously dominant European companies are rapidly being replaced by new, mainly Chinese and other Asian, companies. This could lead to a decrease in learning processes. As experienced companies disappear or experienced engineers leave, the network in which they are integrated might get weaker or even disappear completely. Furthermore, if the European CSP industry vanishes, this could weaken the political case for introducing policy support schemes (Lilliestam 2018).

In a report by (Papadopoulou A. et al. 2019a) the **structure and value chains of CSP projects** were mapped. To do so, a literature survey and a CSP industry survey was conducted. The survey with stakeholders from the CSP industry showed that the industry has been forced to make adjustments to its original business models, i.e. adding additional services and covering more stages of the CSP value chain. This value chain includes solar field equipment and heat transfer fluid (HTF), project development, site related costs, power block, and thermal storage system (see also Figure 9).

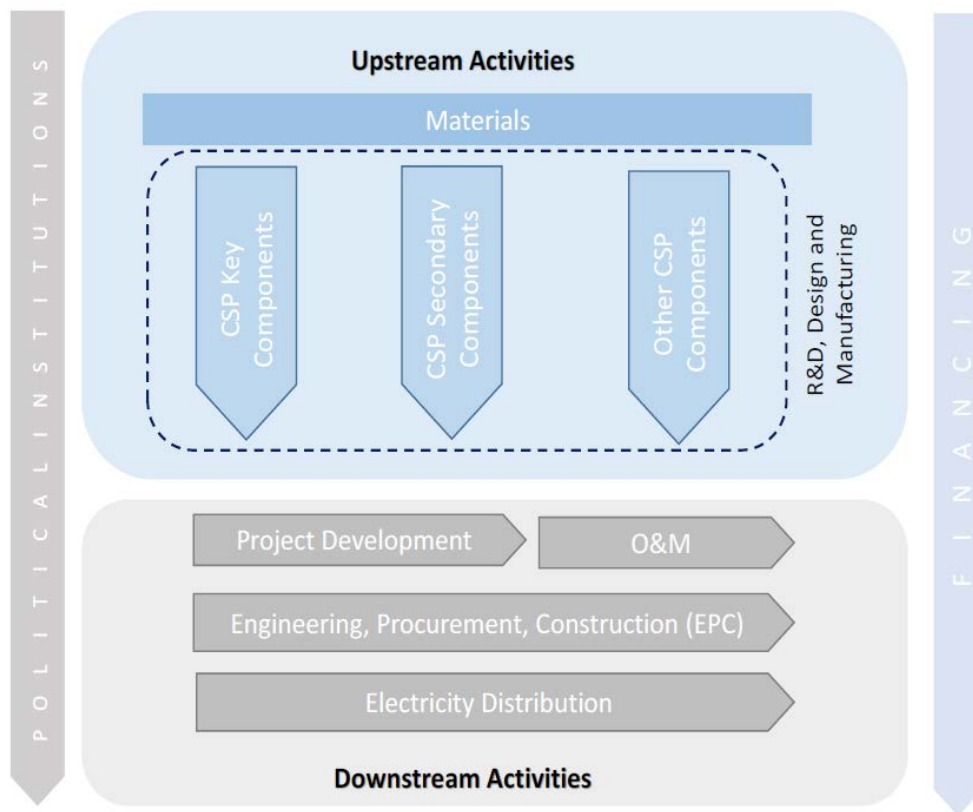


Figure 9: Main components of the CSP value chain (Papadopoulou A. et al. 2019a)

Moreover, due to the recent, low CSP deployment rates, the CSP industry (i.e. the stakeholders that participated in the survey) has been forced to modify their value proposition by adding other technologies to their portfolio. It is expected that the transformation of the electricity market, so that ancillary and balancing services are provided, combined with the carbon emission allowances, will offer additional revenue streams (Papadopoulou A. et al. 2019a). Moreover, the type of economic support mechanism offered to CSP projects was not considered as crucial as the stability of its application (Papadopoulou A. et al. (2019a) and del Rio and Kiefer (2018)).

In order to identify the **role of different economic support schemes and business models on the competitiveness of CSP**, (Papadopoulou A. et al. 2019a) conducted a CSP industry survey with members of the European Solar Thermal Electricity Association. The aim of the survey was to provide a clear picture of the CSP's value chain and the allocation of the costs and benefits to the relevant stakeholders. Furthermore, the survey helped to identify parameters, which would lead to further implementation of CSP projects. Figure 10 shows the answers to the question: “How probable would be for your company to implement a CSP project in a country under this support scheme?”.

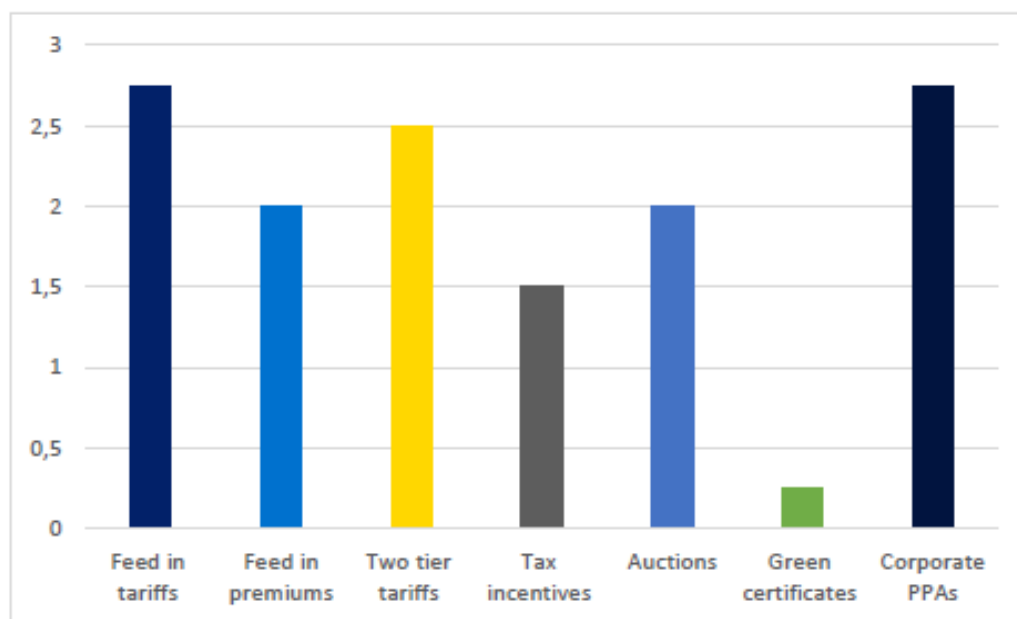


Figure 10: Likelihood of engagement in future CSP projects, depending on the support mechanism; (Papadopoulou A. et al. 2019a)

The likelihood to engage in future CSP projects is higher, if feed in tariffs or corporate PPAs are in force. If the support mechanism is green certificates, the likelihood to plan a CSP project is the lowest (Papadopoulou A. et al. 2019a). Furthermore, the policy goals in the importing and exporting countries should be taken into account (Papadopoulou A. et al. (2019a) and del Rio et al (2019)).

Although, on a global scale, the expansion of CSP is much slower than that of PV and wind and slower than past projections prophesized, several hundred of MW are under construction in seven countries and over one thousand are under advanced development. Therefore, apparently the survival of the CSP technology no longer depends on the continuation of one or two support schemes and is less dependent on single policies. (Lilliestam 2018)

A further factor that has a **significant impact on the competitiveness of CSP are geopolitical aspects** and here in particular the role of oil and gas in the national and regional energy strategies. Even though the literature is still dominated by oil and gas geopolitics, a literature review by (Escribano et al. 2019) identified four interesting aspects concerning CSP: First that the impacts of the energy transition have only recently emerged in geopolitics and academic literature. Second, the literature review has identified several geopolitical externalities related to renewable energies (a trend towards minimizing negative externalities like new dependencies and vulnerabilities and towards emphasizing positive externalities like increased human security and safety). Third, the academic research attracted the interest of think tanks, which contributed to bring renewables to the European geopolitical energy landscape. Fourth, official energy security strategies continue missing the geopolitical externalities of renewables. There does not seem to exist a clear strategic vision

regarding energy security and geopolitical dimension of RES cooperation. Expert interviews showed that the experts were aware of the importance of renewables in geopolitics, however, CSP does not even appear in governments' energy security strategies. The immediate urgencies of fossil geopolitics overshadow the long-term strategic implications of renewables and especially CSP, and most analysts still consider CSP as "immature" and a "niche" technology predestined to "fringe" geopolitics. (Escribano et al. 2019)

A more **general review of the drivers and barriers that impact the competitiveness and the resulting deployment of CSP** was done through a literature review conducted by (Del Río and Kiefer 2018) for the past and the future. The identified drivers and barriers were ranked according to the views of investors and other relevant stakeholders involved in CSP.

Barriers for CSP in the past were higher costs, retroactivity, lack of stability, ambition of targets, and low levels of deployment support. Retroactivity, lack of stability and low deployment support are probably related to the policy conditions existing in the country where virtually all the CSP capacity had been installed in the EU. Concerning the barriers perceived as most relevant in the future (2030), these include higher costs, limited resource potentials (DNI) and the retroactivity, lack of stability and ambition of targets. The least relevant are low competence in the CSP technological innovation system, risk of environmental pollution and low international knowledge collaboration. Higher costs will continue to be relevant as a barrier, despite the perception that the future competitiveness of the technology will not reside in its LCOE, but its system value. DNI is rather a precondition than a driver, but it can also be a barrier compared to the higher DNI levels outside the EU.

According to experts, past **drivers** of CSP were deployment support, policy framework conditions, policy ambition and the technology being regarded as proven (low technology risks). Less relevant were carbon prices, complementary with PV and the cooperation mechanisms. The most relevant drivers for CSP in the future are the dispatchability and the associated higher value compared to other, intermittent energy sources, policy framework conditions and policy ambition, and the complementarity with PV. As least relevant drivers local manufacturing capabilities, a strong knowledge base and knowledge generation in the EU and the existence of a dominant design were identified.

It is interesting to note, that the perception of the importance of the drivers to deployment clearly differs between the past and the future. In particular, the dispatchability of the technology is supposed to be highly relevant in the future, whereas its relevance is low in the past. This is due to the fact that the CSP technology could play a compensating role in an electricity system with high shares of volatile renewable energies. The high cost of CSP is deemed a very important barrier in the past as well as in the future. However, cost reductions are not perceived as a main driver of the technology in the future and therefore, it is supposed that the competitiveness of the technology is expected to be related to the higher system value of the technology. Finally an interesting result worth mentioning is the negligible role of carbon prices as a driver of the technology, which confirms

previous research on its limited influence on high cost-gap technologies and the need to complement it with other instruments in order to encourage their uptake (Del Río and Kiefer 2018).

TECHNO-ECONOMIC PARAMETERS AND MARKET ENVIRONMENT

Key issues

- ✖ Parabolic troughs have been and remain the dominant CSP technology choice on a global scale, however, solar towers might have a breakthrough and take over in the future.
- ✖ Costs for CSP plants are declining fast, especially for solar towers. Solar tower plants announced in 2018 were already cheaper than solar troughs, however, some of these projects have been cancelled so the actual cost trend is still unclear.
- ✖ There is a trend towards larger thermal storages and higher load factors as well as more diverse technology configurations in recent CSP plants.
- ✖ LCOE decreases further with storage size.
- ✖ However, the high costs of CSP projects compared to other RE technologies such as wind and PV is still the main barrier and the parameter with the highest impact on the LCOE.
- ✖ The European CSP industry shrinks, in EPC and project development, previously dominant European companies get replaced by new, mainly Chinese and other Asian companies.
- ✖ The European CSP industry has tried to adjust its business models in order to remain operational.

Crucial requirements

- ➡ Technology cost for CSP needs to be reduced further.
- ➡ Market design needs to recognize the value of CSP as a dispatchable RES technology: In a market setting with high shares of PV and wind and rising CO₂ and natural gas prices, high market values for electricity generated by CSP can be achieved. Ancillary and balancing services offered by CSP can further support this.
- ➡ Policy ambition is crucial: In a possible future electricity with high RES shares and ambitious emission reductions, CSP could play out its main operational advantages - dispatchable, renewable, and CO₂-free generation of electricity.
- ➡ Regional cooperation needs to be pushed by the development of concrete regulatory solutions and related pilot projects
- ➡ Regional initiatives are the main vehicle for coordinating the practical implementation of the new European cross-border regulatory framework.
- ➡ National and regional energy security strategies should recognize the value RES cooperation in general and the opportunities of CSP in particular.

- ✕ If the European CSP industry vanishes, this could further weaken the political case for introducing support schemes for CSP.
 - ✕ The dispatchability of the technology will be a highly relevant driver for its deployment in the future.
 - ✕ Thermal storage is a relatively inexpensive form of storage, which is already competitive for longer storage durations today. By supporting CSP, Europe also promotes this storage solution which is expected to become the most valuable part of this technology in the future.
- ➡ Development of cross-border transmission grid infrastructure is crucial.

2.2 Political and regulatory framework

The implementation of collaborative approaches in RES development requires a favorable political landscape and a conducive regulatory framework for cooperation on both European and national levels. Therefore, MUSTEC analyzed the determinants for the failure of a broad use of RES cooperation mechanisms in the past and investigated the policy variables affecting the deployment of CSP to draw conclusions on the barriers and obstacles that need to be taken into account when aiming at enhanced RES cooperation in the future.

2.2.1 *RES cooperation mechanisms in the EU in the past (2009-2020)*

Cooperation mechanisms were already introduced by the European Commission in 2009 to support the EU Member States in reaching their binding 2020 RES target shares in a cost-efficient way by allowing to generate energy from renewable sources at locations with high RES potentials and/or low system integration costs, thus minimizing the overall system costs. However, the four potential modes of cooperation that were defined in the RES Directive 2009/28/EC, i.e. joint projects between Member States (Art. 7) or Member States and third countries (Art. 9), joint support schemes (Art. 11) and statistical transfers between Member States (Art. 6), have hardly been used so far. The only examples of RES cooperation in the EU until today comprise statistical transfer of RES electricity of Estonia and Lithuania with Luxembourg, joint PV auctions between Germany and Denmark and a joint certificate scheme established between Sweden and the non-EU country Norway (cf. analyses in (Caldés N. et al. 2018) and (Essig et al. 2019)). However, none of these cases involved CSP projects.

Regarding the use of cooperation mechanisms in the past, (Caldés N. et al. 2018) investigated in detail, which factors might have led to the limited use of cooperation mechanisms in the past and conducted an expert consultation for assessing the relevance of the most relevant determinants in this regard. The most relevant factors can be differentiated into the categories: technical, public-acceptance, political, geopolitical, legal, environmental and economic factors. Among these factors, environmental and economic factors were identified as the strongest drivers when it comes to the usage or non-usage of RES cooperation mechanisms, while legal complexity, conflicting political and geopolitical interests as well as public acceptance issues (especially in the potential off-taker and transit countries) were identified as relevant barriers (see Figure 11). Potential cost savings in RES target achievement, were identified as drivers for both, potential host and off-taker countries, while industry development and job creation are drivers in particular in the host countries of potential RES cooperation projects (see more differentiated analysis in Caldés N. et al. (2018) and Caldés N. et al (2019)). Geopolitical risk factors (e.g. control over national energy supply), potential political resistance from electricity transit countries as well as heterogeneities regarding regulated energy prices and prevalent support schemes, constitute barriers for both, host and off-taker countries.



Figure 11 Influence of different factors on the use or non-use of RES cooperation: Factors with a positive score constitute drivers, factors with a negative score are barriers to RES cooperation (source: Caldés et al 2018).

Based on these results, policy interventions seem particularly relevant in addressing the communication of potential benefits of RES cooperation and to enhance the associated public acceptance in potential-off-taker (and transit) countries, as well as to reduce legal barriers related to regulated energy prices, uncertainty on state aid compliance and heterogeneous legal frameworks in the EU Member States to create a level playing field for RES electricity across the EU.

The design of policy measures should thereby specifically address the varying relevance of individual barriers in different types of countries and build on a policy mix of direct and indirect measures. Policies that could help to activate key drivers of cooperation would be, for example, provision of EU guidance, enhanced access to finance and other, indirect policies. On the other hand, measures to address the reduction of the main barriers for RES cooperation could include public awareness campaigns for communicating the benefits of cooperation and likewise the provision of EU guidance and information on legal barriers. (cf. Caldés N. et al 2019).

2.2.2 *Framework conditions for CSP deployment in the EU*

The deployment of individual RES technologies in general and CSP in particular as well as the engagement in RES collaboration mechanisms eventually depend on the **national energy policy interests of the individual Member States, their technology preferences and their strategies for enhancing the flexibility of their electricity system**. The multitude of variables that play a role in this regard have been compiled systematically by (Lilliestam et al 2019). They comprise, for example, the shares of intermittent and dispatchable renewable energy sources in the national electricity system, the level of interconnectedness with the neighboring countries, the availability of energy storage capacities and the degree of sector coupling (e.g. the integration of the electricity sector with the heating, cooling and transport sector and the role of electric mobility or hydrogen technologies). In addition, the national policy focus on energy efficiency and enhancing solutions for demand response plays an important role as all these options can also serve to enhance system flexibility. Against this background, the national preferences and the associated strategies and regulatory frameworks regarding the various options for enhancing system flexibility will define whether there will be a niche for the (collaborative) development of CSP.

The in-depth analyses of the EU Member States' future energy policy pathways show that all countries seek to strongly decarbonize their power systems, which involves substantial expansions of intermittent renewable energy technologies. However, today the development of flexibility options is largely underrepresented in the national energy strategies and the expansion of other low-carbon technologies, such as nuclear power or Carbon Capture and Storage (CCS), do not play a role in any of the countries. Against this background a niche for trading dispatchable renewable electricity, such as electricity generated by CSP, could emerge towards the 2030 horizon when ambitious fossil-fuel phase out decisions are to be realized while ensuring system flexibility. (Lilliestam et al 2019)

The policy priorities of importing and exporting countries have an impact on the attractiveness of different features of CSP projects. For example, dispatchability would be the most important feature for the exporter country, followed by socio-economic benefits, while the cost of the project would be the most relevant factor for the importing country (del Rio and Kiefer 2019).

Besides the national plans for RES deployment and the strategic plans for enhancing electricity system flexibility, also their **fossil fuel strategies and related geopolitical factors** affect the potential role of CSP in the future European energy system. Especially the development of the European gas sector plays a crucial role for the demand for dispatchable renewables and thus the question whether CSP could contribute to system flexibility in Europe. Investments in gas infrastructure and the establishment of longstanding supply relationships lead to path dependencies in the energy supply of the future. The geopolitical strategies and energy relations vary widely among the EU Member States but empirical analyses revealed that neither CSP nor RES cooperation play a relevant role in the Member States' energy security strategies so far (cf. (Escribano et al. 2019)). These findings call for a stronger consideration of the energy security benefits of RES deployment in general, and collaborative RES approaches in particular, in the strategic development of the European energy sector. In this context, also the provision of more budgetary and regulatory incentives for cooperation on an EU level and a stronger emphasis on the public communication of the benefits of the European electricity market integration (incl. transmission interconnections) constitute significant measures.

A systematic analysis of the **drivers and barriers for the market uptake of CSP in the EU**, considering both the system perspective as well as the viewpoints of relevant stakeholder groups, in particular RES investors, is presented by Del Río and Kiefer (2018). A combination of literature research and different expert elicitation methods allowed an identification and ranking of the most relevant drivers and barriers for CSP deployment in the past and future.

As the main (past and future) driver or benefit of the CSP technology, stakeholders frequently mentioned the dispatchability of the produced electricity and the associated higher market value. In this context, also the complementarity of CSP with PV was mentioned as a major benefit. The maturity and good performance of the technology were seen as further drivers, as well as the accumulated knowledge and experience gathered through CSP projects (especially regarding parabolic trough) in the past.

The identified main barriers for CSP deployment emphasize the higher costs of the technology compared to other RES technologies (here especially the competition with PV), unstable policy frameworks (in particular referring to the past retroactive policy changes in Spain) and insufficient economic support levels. These barriers remain relevant for the future deployment of CSP as well. Investors further stress the importance of administrative processes and the procedures for obtaining construction permits and grid connections, as also these non-economic factors can constitute significant barriers to RES project development (cf. Table 1). In addition, land-use conflicts and the availability of water play a role in this regard. Further, the fact that technology expertise

increasingly moves out of the EU was mentioned as a further barrier relevant for future CSP deployment.

Consequently, key requirements to boost CSP deployment in the future are a stable and reliable policy framework (both nationally and on EU level), sufficient economic support and access to finance, a favorable market design and ambitious technology deployment targets to ensure long-term planning reliability. Also technology cost reductions through R&D support and enhanced knowledge collaboration for the further development of the technology in the EU were mentioned as relevant future drivers.

Table 1 Summary of investors' views on the drivers and barriers to CSP deployment in the EU in the past (survey results)

	PARABOLIC TROUGH	SOLAR TOWER
DRIVERS	-Maturity. -Expected performance. -Dispatchability. -Previous technological experience. -Previous project realization experience. -Accumulated knowledge.	-Dispatchability
BARRIERS	-Administrative processes -Construction permits -Grid connection	-Thin markets for solar-specific components -Administrative processes -Construction permits -Grid connection

Source: Del Río and Kiefer (2018)

The above results further extend and confirm the findings of Del Río et al. (2018) who provide an integrated analysis building on Caldés N. et al. (2018) and Del Río and Kiefer (2018) to identify the **most relevant drivers and barriers to the use of RES cooperation mechanisms specifically for CSP**. According to their expert consultation, the most relevant drivers for the use of the cooperation mechanisms for CSP in the future include the dispatchability of CSP, the potential creation of new domestic jobs and industrial development and the complementarity of CSP with PV (see Figure 12). A major driver or requirement are ambitious policies and CSP deployment targets and the potential mandatory opening of national RES support schemes. The most relevant barriers to CSP cooperation, on the contrary, are the higher costs of CSP compared to other RES technologies; heterogeneous regulated energy prices and disparate RES support schemes and the Member States' resistance to lose sovereignty over the national energy market. Also a lack of electricity interconnections capacities and public resistance to cooperation projects are regarded as a relevant barrier. The results underpin the importance of future cost reductions for CSP and a stronger electricity market and RES policy integration (including specific support and guidance for the use of cooperation mechanisms) across the EU to facilitate the use of the cooperation mechanisms for CSP.

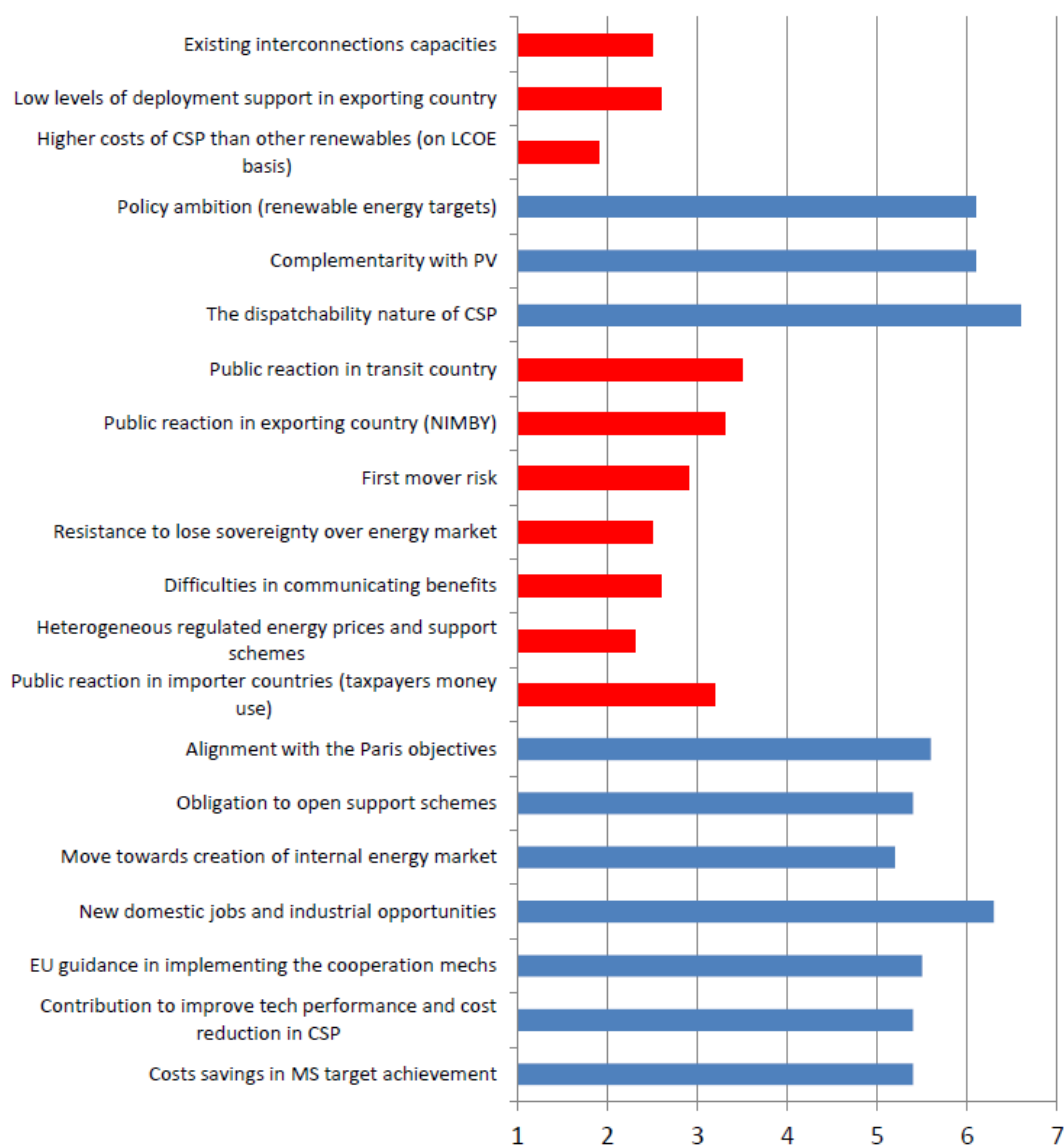


Figure 12 Most relevant drivers (blue) and barriers (red) to the use of the cooperation mechanisms for CSP in the future based on a stakeholder survey. Del Río et al. (2018)

2.2.3 RES cooperation mechanisms and CSP in the post-2020 policy framework

In May 2019, the EU adopted a new policy package that defines the framework for renewable energy deployment for the time horizon 2020-2030. This policy package ‘Clean Energy for all Europeans (CE4ALL)’, includes a new EU-wide 2030 target of at least 32% for the share of renewable energies in gross final energy consumption, however, in contrast to the framework up to 2020, it does not specify binding national targets anymore. Instead, each Member State is required to draft a National Energy and Climate Plans (NECPs) that specifies its envisaged (non-binding) RES share in 2030. In

the context of RES cooperation and collaborative CSP development, the most relevant documents under the CE4ALL package are the Recast Renewable Energy Directive 2018/2001¹, which defines the binding RES target on European level and sets guidelines for renewable energy support schemes and cooperation, and the Governance Regulation 2018/1999², which establishes a governance system for the implementation of energy and climate strategies on national level (i.e. the NECPs). The Governance Regulation also defines mechanisms and instruments that can be applied if the collective EU RES target is missed, i.e. if a ‘delivery gap’ occurs. However, the Governance Regulation does not provide a detailed design of these gap-filler measures.

Regarding the support for electricity from renewable sources, the post-2020 EU policy framework defines that economic support can only be granted if it gets allocated through technology-neutral, competitive procedures and only in the form of either fixed or sliding market premiums. However, Member States may still focus their RES support auctions on specific technologies if they can demonstrate that a technology-neutral tender would lead to suboptimal results. This is particularly relevant if CSP projects are concerned, since the LCOE of CSP is still higher, compared to other RES technologies, such as solar PV or onshore wind. The selling point of CSP installations is their dispatchability, meaning that the thermal energy generated by sunlight can be stored for several hours before it is converted into electricity. Consequently, the success of CSP projects in competitive tendering procedures depends critically on the design of the auctions and here in particular on whether the energy storage option is valued in the evaluation criteria of the tender or not.

In case that a RES delivery gap on EU level should occur, different **‘gap-filler’ measures** can be applied by those Member States that fail to reach the reference points defined in their NECPs. Besides making enhanced national efforts, i.e. the implementation of national RES support schemes, the ‘gap-filler’ measures include the option to contribute to the a European wide fund for the ‘European Union Financing Mechanism’ or to engage in RES cooperation mechanisms with other EU Member States that have a surplus of RES generation.

With respect to RES cooperation, the recast RES Directive (2018/2001) includes some new instruments in addition to the RES cooperation mechanisms set out in the 2009 RES Directive. Firstly, statistical transfer of RES electricity shall be facilitated by the creation of a Union Renewable Development Platform (URDP), which acts as a match-maker and aims to reduce administrative hurdles for RES cooperation. Secondly, the Commission encourages the opening of support schemes for electricity generated from RES to producers located in other Member States. At present, the suggested opening of RES support schemes is voluntary (with an indicative share of min. 5 % from 2023 to 2026 and min. 10 % from 2027 to 2030), but the Commission will assess the option of a mandatory opening by 2023. This measure would imply a significant push for cross-border RES deployment and might create new opportunities for the collaborative development of CSP projects.

¹ <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN>

² <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999&from=EN>

The **‘EU Financing Mechanism’** will be established by January 2021 and its detailed design features are not yet defined at the time of writing this report. However, the key elements of the fund are as follows: Once a RES delivery gap should be identified, Member States with RES deployment lower than their intended NECP trajectory have the option to make a financial contribution to the fund. The funds are then used to support RES deployment in other EU Member States to make sure that the collective target is reached. Countries that would like to act as host countries of RES projects supported by the fund can specify the capacities and RES technologies with which they would like to contribute. Off-takers, on the other hand, can indicate their demand and the maximum price they are willing to pay. The Commission would then organize EU-wide auctions allocating feed-in premiums to these projects.

Another new element in the recast RES Directive 2018/2001 that explicitly addresses cooperation is the so called **‘Enabling Framework’ for renewable energy**. The recast RES Directive 2018/2001 stipulates that Union funds and other funds should be used to enhance the integration of RES technologies and storage facilities in the EU electricity system, to reduce cost of capital for RES, to increase system flexibility and interconnection capacities and to promote cooperation between the EU Member States. Possible means by which this support could be provided are low-interest loans, grants, or a mix of both that could be granted also to joint projects between Member States. Depending on the detailed implementation of these measures, which is not clear at the time of writing of this report, the enabling framework could thus play a relevant role for the expansion of CSP as CSP with its dispatchability could explicitly add to the European electricity systems’ flexibility.

A further instrument that could be relevant for CSP expansion in Europe, which is however not part of CE4ALL package, is the **‘Connecting Europe Facility’ (CEF)**. The spectrum of projects that are eligible for funding available under the CEF for the period 2021-2027 has recently been expanded and an amount of 8.7 billion Euro will be available for the support of cross-border projects in the field of renewable energy (c-b projects in RES). The financial support can be allocated to technical or feasibility studies for such collaborative RES projects. A CSP project developed collaboratively between two Member States would likely qualify for funding under this instrument and the provided grants could help to increase the competitiveness of CSP significantly.

However, whether such collaborative CSP projects will actually materialize and will be able to benefit from the above described instruments and mechanisms eventually depends on the interests and the strategic focus of the individual Member States, i.e. their willingness to foster CSP as a dispatchable RES technology rather than focusing on other technology options to increase system flexibility. CSP deployment has only been included in the draft NECPs of Spain, Portugal, Italy, Greece and Cyprus, whereby the existence of a national CSP industry in Spain represents an additional driver to develop the technology.

Further indicators for the probability that EU Member States might engage in potential future (CSP) cooperation projects are the likelihood that they reach their RES targets as well as the resource potential for the technology. Against this background, Spain and Italy are the Member States that

are most likely to engage as host countries in future CSP cooperation projects (cf. [Figure 11](#)). Taking the target achievement of the 2020 targets as a proxy, several Member States might be at risk of also failing to reach their NECP trajectories in the future. These countries could be potential off-taker countries in RES cooperation projects in the future. However, the higher LCOE of CSP compared to, e.g. PV or wind energy onshore, will likely only be accepted if physical transfer of electricity is possible and the off-taker actually benefits from the dispatchability of the generated electricity (e.g. from Italy to Malta, or from Spain to France). This would not be the case if statistical transfer takes place. Here, the off-taker country will aim at minimizing support costs and has no benefit from the dispatchability. (cf. Essig et al (2019) and del Rio et al (2019))

Thus, assuming a purely economical (meaning LCOE-based) optimization of RES collaboration projects, CSP projects will not be competitive compared to, e.g. PV and wind onshore. However, in case that physical transfer of RES electricity between the collaborating parties is possible, CSP combined with storage could add to system flexibility in the host and off-taker country and thus increase the value of the electricity generated through a collaboratively developed CSP project (Essig et al. 2019).

A discussion of the individual instruments and their potential relevance for the implementation of collaborative CSP projects among EU Member States in the future is summarized in Table 2 and presented in detail in Essig et al. (2019).

A broader view on cooperative approaches in the field of energy in the EU was added to the analysis of the political and regulatory framework by (Papadopoulou A. et al. 2019b) who conducted a review of six regional cooperation initiatives in the EU: The North Seas Countries' Offshore Grid Initiative (NSCOGI); the Pentilateral Energy Forum (PEF); the Baltic Energy Market Interconnection Plan (BEMIP); the Desertec Industrial Initiative (Dii); the ENTSO-E's Regional Groups and Electricity Regional Initiatives established by the European Regulators' Group for Electricity and Gas (ERGEG). The main lessons learned from the analysis of these initiatives were that, in order to foster cooperation, the development of concrete regulatory solutions and related pilot projects are crucial. Furthermore, underlying policy issues should be taken into consideration. In facilitating regional cooperation, a synchronization with European networks and Commission leadership can be important. A critical parameter is compatibility for the interconnection of Europe with other regions. The emergence of compatible solutions across regions can be enhanced by region overlaps. Regional initiatives are the main vehicle for coordinating the practical implementation of the new European cross-border regulatory framework. The majority of these lessons learned need to be addressed by any regional initiative to promote the use of CSP in order to be successful (Papadopoulou A. et al. 2019b).

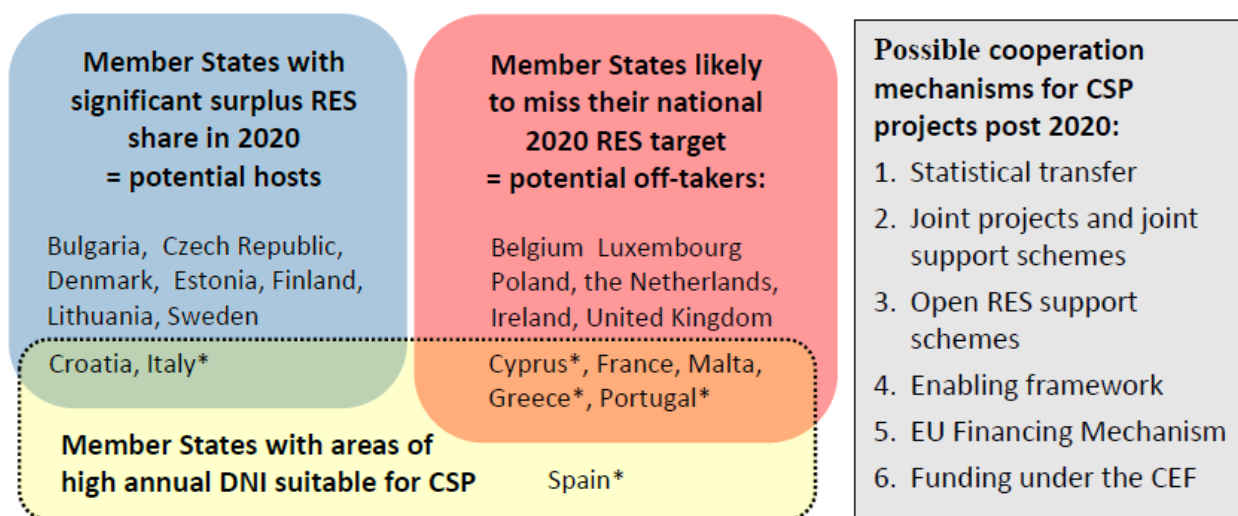


Figure 13: Summary of potential host countries, off-taker countries and policy instruments potentially relevant for CSP cooperation 2020-2030 Essig et al. (2019)

Overview of potential host countries (blue box) and off-taker countries (red box) for cooperation, and Member States with areas of high DNI values beneficial for CSP projects (yellow box). The * indicates countries which included CSP in their draft NECPs from December 2018. Spain is expected to just meet the 2020 target. The grey box summarizes the potential instruments that might promote CSP cooperation projects in the 2020-2030 timeframe.

Table 2 Assessment of the potential relevance of policy instruments for future CSP cooperation projects in Europe (Essig et al 2019)

Legal document	Instruments potentially relevant for EU CSP cooperation	Assessment of potential implications and level of relevance for CSP cooperation
Renewable Energy Directive (2009/28/EC)	• Cooperation mechanisms: - o Joint Projects (Article 7) - o Joint Support Schemes (Article 11) - o Statistical transfers (Article 6)	No impact on CSP cooperation - Hardly any use of cooperation mechanisms in general and no application to CSP in the past.
Recast Renewable Energy Directive 2018/2001	• Cooperation mechanisms: - o Statistical transfer and establishment of Union Renewable Development Platform (URDP) for facilitated matchmaking (Article 8): Member States can publish their expected excess or deficient amount of RES energy and a tentative price for a statistical transfer of RES.	Impact on CSP cooperation unlikely - Additional elements to promote coordination and cooperation among Member States have been introduced, especially through the establishment of the URDP. - However, the impact of statistical transfer on potential CSP cooperation projects in the future will likely be very limited as statistical RE transfer does not value the dispatchability of CSP and thus makes it less competitive compared to RES technologies with lower LCOE.
	- o Joint Projects (Article 9) - o Joint Support Schemes (Article 13)	Impact on CSP cooperation highly unclear - The relevance of joint projects and joint support schemes, likely realized in the form of cross-border auctions, strongly depends on the auction design (in particular the technology specification) and the level to which the dispatchability of CSP is valued in the detailed auction design.
	• Opening of RES support schemes: - o Suggested indicative share of a minimum 5 % from 2023 to 2026 and a minimum 10 % from 2027 to 2030 (voluntary).	Potentially relevant for CSP cooperation - A mandatory opening of support schemes after 2023 would imply a significant push for cross-border cooperation in RES deployment.

Legal document	Instruments potentially relevant for EU CSP cooperation	Assessment of potential implications and level of relevance for CSP cooperation
	○ By 2023, review of utilization and decision about the possibility of a mandatory opening (Art. 5/5). ● “Enabling framework”: Use of Union funds and additional funds, for different activities to foster RE deployment: ○ Reduction of the cost of capital for RE projects; ○ Implementation of projects and programs for enhanced integration of RES into the energy system and to increase system flexibility; ○ Development of the electricity grid including storage facilities and other grid related actions to reach the 15 % electricity interconnection target by 2030. ● Promotion of cooperation between Member States [...] through joint projects, joint support schemes and opening of support schemes for RES deployment.	- The opportunities for cross-border CSP projects, however, depend on the interests, i.e. the technology focus of the individual countries. Potentially high relevance for CSP cooperation - Activities under the enabling framework could be of direct relevance to CSP cooperation projects as they explicitly address the support of projects that can contribute to increasing system flexibility and storage options. - Support may be granted in form of low-interest loans or grants for CSP projects that help to increase the EU electricity system flexibility. - Reduction of capital costs for RES projects could support RES cooperation projects by making RES more competitive in the cross-border context as costs of financing renewables differ substantially between the EU Member States. The use of risk-reduction instruments could substantially decrease the investment needs for CSP projects and help to reduce differences in the competitive market environment among Member States. This would help to create a more level playing field that would implicitly foster RES cooperation. - The enabling framework explicitly foresees the enhancement of regional cooperation and joint projects in RE, which implies that in particular cooperation projects (including CSP) would be in the focus of the measures.

Legal document	Instruments potentially relevant for EU CSP cooperation	Assessment of potential implications and level of relevance for CSP cooperation
Governance Regulation 2018/1999	• Union financing mechanism: To be established by January 2021, no detailed design yet, main characteristics: - o Competitive tenders - o Support granted as feed-in premiums on top of the market prices. - o Member States have the right to decide about RE installations in their territory. - o Commission will provide rules for the implementation (e.g. regarding tender design, participation, maximum premium and duration of the payments). - o Financing mechanism shall promote RES deployment irrespective of a delivery gap and support the enabling framework. Hence, it may also provide low-interest loans, grants, or a mix of both to joint projects between Member States [...]. For this, Union funds, contributions from private sector or Member States may complement the financing.	Potentially high relevance for CSP cooperation - The financing mechanism could be relevant for CSP cooperation projects if auctions on EU level would be technology-specific and would be targeted specifically on the benefits of CSP (i.e. dispatchability / storage options). - If auctions would be technology-neutral CSP would likely not be competitive. - Collaborative CSP projects could also be supported through low-interest loans and/or grants for feasibility studies or for the actual project implementation.
Connecting Europe Facility (CEF)	• Support to ‘c-b projects in RES’: 2021-2027 budget of 42.3 billion Euro of which 8.7 billion € are dedicated to the promotion of the clean energy transition in accordance with the “CE4All” package. • Support to cross-border RE projects [...] for technical, preoperational or feasibility studies and/or work.	Potentially high relevance for CSP cooperation - Based on the preliminary information it is well conceivable that CSP cooperation projects would qualify for funding, as a joint CSP project could add flexibility to the EU energy system (EU added value) and would depend on additional support due to the high LCOE (funding gap).

Legal document	Instruments potentially relevant for EU CSP cooperation	Assessment of potential implications and level of relevance for CSP cooperation
	• Eligibility for grants requires: - o Cooperation between countries as set out in Directive 2009/28/EC - o EU-added value - o Existence of a funding gap.	- CSP cooperation projects could receive grants covering up to 50% of the costs and/or funding for feasibility studies. - Support could be complementary and synergetic to the mechanisms under the 'gap-filler' and the 'enabling framework' as it would complement actions taken at bi- or multinational level as well as at EU level on cross-border RES cooperation. - However, due to the high installation costs for CSP and competition with other technologies/projects the limited CEF fund will likely only be able to support very few cross-border CSP projects.

POLITICAL AND REGULATORY FRAMEWORK

Key issues

- ✗ Cooperation mechanisms under Directive 2009/28/EC have hardly been used and never involved CSP projects
- ✗ National energy policy interests (e.g. to increase electricity system flexibility or for industry development) are the key determinant for RES deployment
- ✗ Currently, no country has specific plans for increasing system flexibility
- ✗ Higher LCOE of CSP compared to PV and wind onshore constitute a competitive disadvantage for the technology
- ✗ Post-2020 EU-wide RES target of (at least) 32% and absence of binding national targets emphasize relevance of collaborative approaches among Member States in the future
- ✗ New instruments in post-2020 framework (CE4ALL) could be relevant for CSP cooperation: Applicability of 'enabling framework' and the 'EU financing mechanism' to CSP projects eventually depend on specific design of the instruments
- ✗ Value of dispatchability of CSP only manifests itself if physical transfer of electricity is possible and not in the case of statistical transfer

Crucial requirements & drivers

- ➡ Further technology cost reductions for CSP are necessary to enhance competitiveness of CSP
- ➡ Policy measures need to allow for targeted (i.e. technology-specific) support
- ➡ RES support policies and in particular the design of RES auctions need to better value positive system impacts as e.g. storage / dispatchability of CSP
- ➡ Measures under the EU's 'enabling framework' could help to reduce CSP project costs
- ➡ Auctions under 'EU financing mechanism' would need to be technology-specific and address CSP in particular
- ➡ Focus on cross-border interconnection capacities needed to enhance flexibility of the European electricity system and to facilitate collaborative approaches
- ➡ Funding of 'cb-projects in RES' through the 'Connecting Europe Facility' (CEF) should take requirements of CSP projects (e.g. regarding project lead times and investment volumes) into account
- ➡ A balanced policy mix should also include indirect measures, for example, for enhancing the communication of the benefits of

RES cooperation and enhancing
public acceptance (see next
section)

2.3 Social acceptance

The uptake and market diffusion of technologies or the use of policy instruments, such as RES cooperation mechanisms, eventually depends on the decisions of various stakeholder groups and their perception of the advantages and disadvantages of the respective technology or instrument. Therefore, the MUSTEC project, in particular work package 3, deals with the identification, consultation and engagement of stakeholder groups relevant for the deployment of CSP and the usage of RES cooperation mechanisms in the European Member States. The work carried out in this work package aimed at identifying barriers and drivers for CSP cooperation from the perspective of various stakeholders and pointing out solutions that are acceptable both from a social and political point of view.

2.3.1 *Relevant stakeholders for CSP cooperation*

Dütschke et al. (2018) found that little scientific research has been done so far, neither on the societal embeddedness of CSP technologies, nor on the factors governing the social acceptance of cooperative approaches for RES deployment.

In a systematic, desk-based screening of stakeholders relevant for a potential cooperative development of CSP projects, Dütschke et al. (2018) thus conceptualized the social acceptance of potential CSP cooperation projects drawing on a revised version of the actor conceptualization of the technological innovation system (TIS) by Hekkert et al. (2011), in a TIS, the stakeholder groups can be categorized into the following categories.

- **Politics, Policy and Institutions:** *In the case of CSP cooperation, relevant stakeholders include, for example, the ministries for energy and economy in each Member State, the European Commission, national regulators or grid agencies, the Agency for the Cooperation on Energy Regulations (ACER) as well as the Council of European Energy Regulators (CEER) on the European level. The intergovernmental organization Union for the Mediterranean (UfM) also has an interest in strengthening the solar industry in the Southern European countries. However, the countries interested in the establishment of cooperation mechanisms might not only be limited to European Member States, but could also include 3rd countries like Morocco, which could export RES electricity to Europe, thereby profiting from well-developed inner European grids and established regulations for RES cooperation.*
- **Research and Education:** This encompasses universities, public and private research institutes as well as institutions that offer specific education and professional training. In the context of CSP cooperation, research institutes and universities with a focus on the technology R&D and research on RES support and cooperation policies are relevant.
- **Supply side:** This category includes all actors directly included in the technology supply chain. For renewable energy projects, this can be divided into the development phase and the operational phase. Stakeholders include project developers, engineering, procurement and

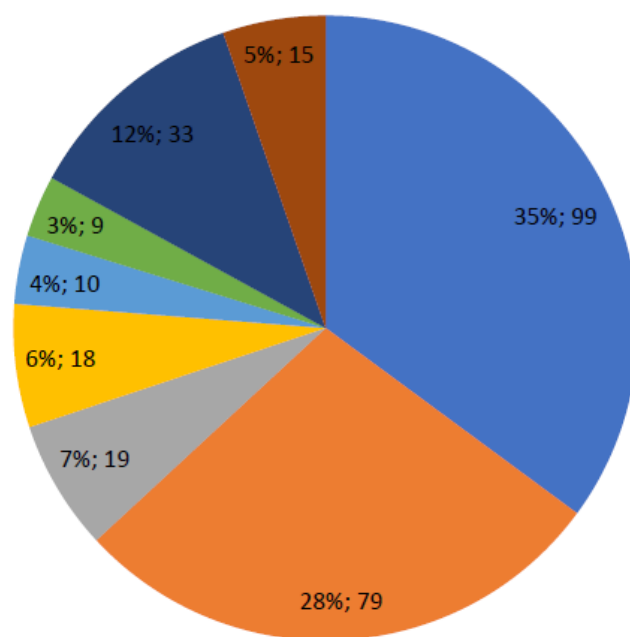
construction (EPC) and component manufacturers. In the operational phase, the power plant owners, and all actors involved in the operation and maintenance are relevant as well as stakeholders involved in the distribution of the generated electricity (such as transmission system operators and operators of electricity exchanges).

- **Demand side:** *Actors on the demand side* include mainly utilities and, indirectly, also private consumers of electricity.
- **Support Organizations:** In the case of CSP cooperation, support organizations include investors and capital providers, networking organizations and other promoters and consultants. An additional category which is particularly relevant in the context of RS cooperation is the so called influencers who provide information and shape opinions. This group includes members of the civil society (voters), local residents and employees, labor unions, media and other opinion leaders.
- **Influencers:** This category summarizes actors that are not directly involved in the CSP innovation system, however, influence the opinions and actions of directly involved actors. This group includes civil society as voters, local residents and employees/labor unions, media and other opinion leaders. Media also plays a role in this group by shaping opinions and providing information to the public.

A first, non-exhaustive compilation of stakeholders across potential host, transit and off-taker countries in Europe has led to the identification of 278 stakeholders from different categories (see Figure 15). The distribution of the identified stakeholders across countries is shown in Figure 14.

The findings of the initial screening suggest that there is a dominance of Spanish and German companies in the TIS for CSP. About 36% of the identified stakeholders are Spanish and 28% German, with a multitude of component manufacturers, project developers R&D organizations and energy (policy) consultants. However, also France and Italy constitute a significant share of the stakeholders with 7% and 6%, respectively. Across the other European countries, only limited numbers of relevant stakeholders could be identified, whereby it has to be noted that European-level organizations with location in Brussels were categorized as Belgian.

Regarding the type of the identified stakeholders, the majority of identified **organizations** can be categorized as **manufacturers of CSP components** or stakeholders from the EPC sector. Further relevant stakeholder groups are power plant operators and project developers as well as support organizations such as e.g. financiers, associations or regional initiatives (see Figure 15).



■ Spain ■ Germany ■ France ■ Italy ■ Belgium ■ Switzerland ■ Other Europe ■ Non-Europe

Figure 14 Stakeholders for CSP and cooperation mechanisms by country (Dütschke et al 2018)

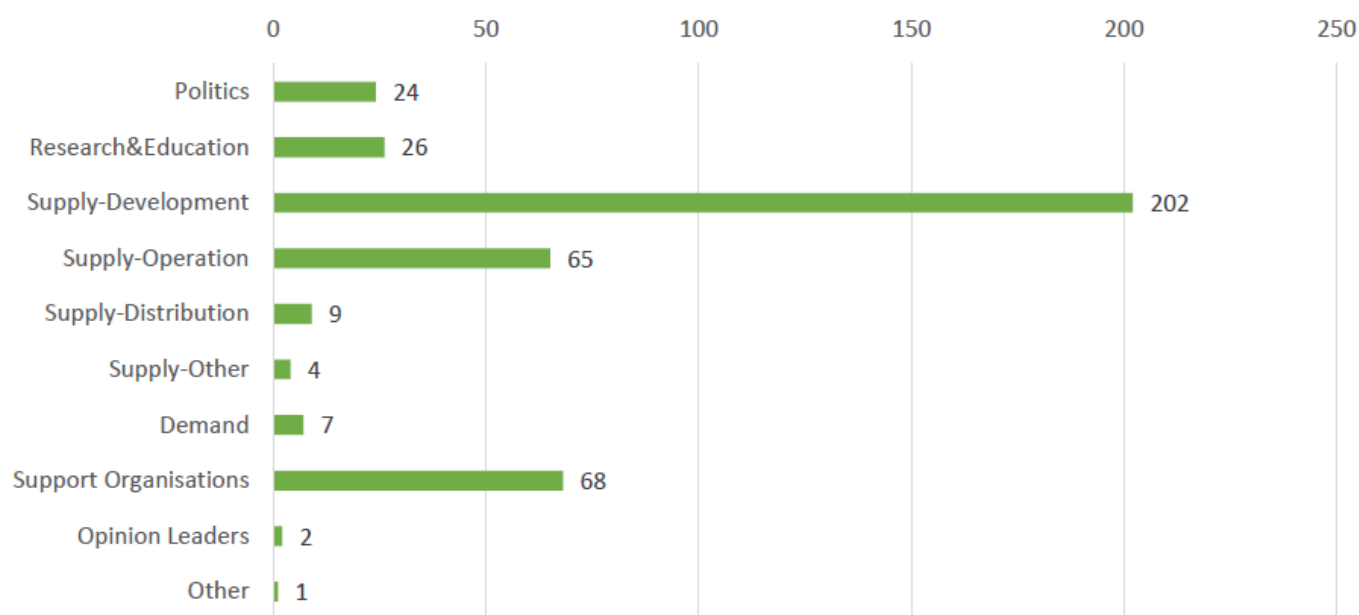


Figure 15 Stakeholders for CSP and cooperation mechanisms by category (Dütschke et al 2018)

2.3.2 Stakeholder perspectives on CSP and cooperation mechanisms

To assess the social acceptance of CSP and cooperation mechanisms, Dütschke et al. (2019) conducted stakeholder interviews across Europe.

For the interviews three dimensions of social acceptance according to Wüstenhagen et al. (2007)) were analyzed: Socio-political acceptance, local acceptance and market acceptance. Thereby, socio-political acceptance refers to the general attitude towards a technology or innovation within a society; community acceptance refers to the local opinion and openness of the stakeholders directly affected by an innovation (e.g. the population living close to a planned CSP plant or transmission line); market acceptance describes the attitude of market actors, such as stakeholders on the supply and demand side, installers or consultants, towards the technology.

The interviewed stakeholders originated from Spain (as a potential host country), Germany, and the Netherlands (as potential off-taker countries) and France (as a potential transit country) complemented by EU level stakeholders. A number of 58 semi-structured interviews were conducted. Interviewees and organizations were selected to reflect a range of positions in the relevant innovation systems. In the interviews the stakeholders were consulted on the main barriers and opportunities/enablers for the implementation of cooperation mechanisms for CSP.

Table 3 gives an overview on how the three dimensions of social acceptance can be applied to CSP and RES cooperation mechanisms and which actors are potentially relevant. The table also gives a brief summary of the major findings of the stakeholder interviews.

Table 3 Social acceptance for CSP and cooperation mechanisms (based on Dütschke et al. (2019))

Acceptance dimension	Aspects for CSP and cooperation mechanisms	Relevant actors	Acceptance for CSP cooperation
Socio-political acceptance	For CSP and cooperation mechanisms socio-political acceptance in all countries involved is relevant, i.e. in the countries providing electricity by CSP, the countries through which the electricity is transferred as well as finally in those countries where the electricity is consumed.	The public; voters; opinion leaders from politics, industry and society in general; media	There is a heterogeneous view on CSP cooperation and no clear public opinion. Cooperation is generally seen as a positive option to mitigate climate change in an efficient way, to enhance European energy market integration and to contribute with dispatchable electricity to the European energy system. However, especially for some actors in off-taker countries, supporting renewable energy projects with public budgets in foreign countries also rises negative associations, especially if cheaper technology options (e.g. PV) are available. Thus, the public communication strategy, i.e. the narrative around potential CSP cooperation projects is a very important issue to achieve a positive public opinion. A potential narrative proposed in the interviews evolves around the idea of a broader cooperation and cohesion within Europe where economically better off countries will also gain in the end from making other member states stronger.
Community acceptance	For CSP, these are inhabitants in sight of a CSP power plant or those living along transmission lines connecting CSP power plants in Southern Europe with more Northern regions. Regarding the cooperation mechanisms, community acceptance is less relevant.	Neighbors / inhabitants of affected areas; local and regional policy makers and administration representatives	For CSP projects local acceptance is not specifically critical, as power plants are typically located in areas with a low population density - given that implementation is guided by the application of transparent procedures that enable participation and local benefits. A positive attitude exists against the background of potential local economic benefits (job creation, industry development).

<i>Acceptance dimension</i>	<i>Aspects for CSP and cooperation mechanisms</i>	<i>Relevant actors</i>	<i>Acceptance for CSP cooperation</i>
Market acceptance	The diffusion of CSP, from a market perspective, includes acceptance by those developing and providing the technology, those actually implementing it and, on the demand side, those using the energy generated. The acceptance of cooperation mechanisms more generally depends on the market structure and price/cost structures of the energy market.	Suppliers (component manufacturers, project developers) including intermediate actors like installers, consultants, but also Distribution System Operators (DSOs) and Transmission System Operators (TSOs) as well as on the demand side utilities and energy consumers including households but also industry	There is a positive attitude on the supply side, i.e. the industry has a strong interest to contribute to CSP cooperation projects. The attitude on the demand side is less clear as electricity is sold on market platforms and individuals are only affected indirectly. Engagement from the demand side does not seem likely.

In summary, the interviews revealed that despite a generally positive perception of CSP cooperation projects by many stakeholders (especially in Spain), there is a lack of impetus from important actors in the innovation system, which would be required to actually drive the development of such projects. Ambivalence and skepticism were observed for many stakeholder groups (policy, societal actors, and to some extent even the industry), especially against the background of national policy interests and doubts about the political stability in the involved countries and the complexity of the associated procedures. The topic is generally considered as low on the political agenda.

Even though many interviewees think that CSP could play an important role in the EU energy system by contributing to achieving the EU climate goals and by supporting the energy market integration and adding to system flexibility, the higher technology cost compared to other technology options (especially PV + storage) is considered as a major drawback. This could lead to societal opposition if public money is spent on the support of such projects. Another important barrier that was mentioned by several stakeholders is the lack of the necessary transmission infrastructure as the interconnection of Spain to Central Europe is weak. Local acceptance issues might also arise from opposition to potential new transmission lines.

2.3.3 Public acceptance of CSP and cooperation projects

Another, in-depth survey study by Oltra et al. (2019) looked further into the drivers and barriers for the social acceptance of joint projects in renewable energies (CSP and wind energy projects) from a public point of view. In this study an online survey was conducted in four European countries (Spain and Germany, Romania and the Netherlands) and comprised replies from 3.200 European citizens. The study included an evaluation of specific hypothetical cooperation projects: German and Spanish citizens were asked to evaluate a joint project in which a CSP plant in Spain provides electricity for Germany. Citizens from Romania and the Netherlands evaluated a project based on onshore wind farms operating in Romania but counting towards the RE target in the Netherlands.

The results of the survey suggest that the majority of respondents has a relatively positive attitude towards RE cooperation projects and perceive them as a fair or good idea to reach renewable energy targets (see Figure 16). In Romania and Spain, the hypothetical host countries of the joint projects, a significant share of the respondents even has a very positive opinion about the projects. More in-depth analyses confirmed that the participants in Spain and Romania perceive the joint projects as more personally relevant, express higher levels of interest and optimism about the projects, perceive the national consequences of these projects as more beneficial and report higher levels of acceptance and support for public investments in these projects, compared to the participants in Germany and The Netherlands (the potential off-taker countries).

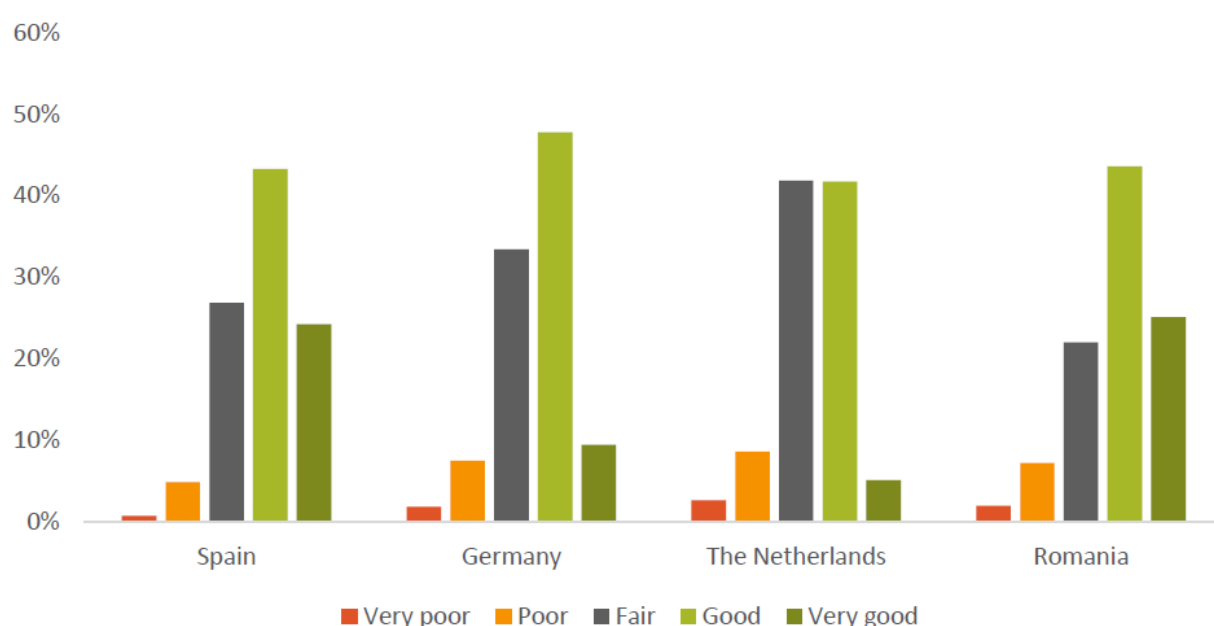


Figure 16 General evaluation of the joint projects by respondents of the four countries (in % per country) (Source: Oltra et al. (2019))

Further, the results showed that the majority of respondents agreed on the necessity to reduce greenhouse gas emissions, to increase the share of renewable energy sources and to make efforts to realize a fully integrated internal energy market. However, the need to build a fully integrated energy market in the European Union was perceived as less relevant relative to the need to reduce emissions and to increase the share of renewable energy sources. Based on the findings, for respondents in Spain and Romania market integration was more relevant than for participants in Germany and The Netherlands. Also the potential impacts of the joint projects on regional development, the stability of the energy supply, industry development or the Energy Union were generally regarded as positive.

A further main outcome of the study is that, even though the awareness of joint renewable energy projects among the population is low, the majority of the respondents in the four study populations (between 59% and 82%) would accept the development of the proposed projects and between 48% and 76% would support public investments in the projects. Thus, it seems feasible to build a positive narrative as suggested in section 2.4.2.

However, the findings also underline that a targeted communication of the potential benefits of joint renewable energy projects as well as the equal distribution of these benefits among host and off-taker countries are crucial to promote higher levels of public support for these projects, especially in the potential off-taker countries. In particular, the benefits of the creation of a more integrated European energy system and the positive impacts on regional economic development should be emphasized. Also the general attitude towards the European Union should be addressed to increase public support for collaborative approaches in general.

More specific suggestions on how and when the different stakeholder groups should be addressed and involved to maximize social acceptance of CSP cooperation projects will be developed in the final deliverable of the Work Package “Stakeholder engagement findings: roadmap and final recommendations” (not available at the time of writing this report).

SOCIAL ACCEPTANCE

Key issues

- ✖ Network of companies and associations exists on the supply side but hardly any actors on the demand side who actively associate with CSP.
- ✖ Despite perception of benefits from joint projects for CSP by stakeholders, impetus from society or important actors in the innovation system is missing and there is a limited interest and a lack of recent discussions in many groups (e.g. policy makers, societal actors, and to some extent the industry itself).
- ✖ Many interviewees think that CSP could play a useful role in the energy

Crucial requirements

- ➡ Application of transparent procedures that enable local stakeholder participation and support the realization of potential local benefits is crucial to enhance local acceptance.
- ➡ Communicating a scenario of ‘supporting a European idea with a project that helps mitigating climate change and stands for efficient use of resources and a win-win-situation between countries’ to enhance socio-political acceptance.

system, e.g. by contributing to achieve climate goals or by adding flexibility to the energy system with dispatchable electricity but they also believe that this could be realized with other technology options, such as PV and storage.

- ✖ Local acceptance is not seen as specifically critical for CSP as project implementation usually takes place in less densely populated areas. Of course, the application of common sense procedure like creating local benefits are indicated.
- ✖ Socio-political acceptance might become a major issue and depends on the narratives that will emerge (e.g. the negative scenario of 'investing large sums of money in a foreign country for insecure outcomes' will put social acceptance at risk).
- ✖ The general public attitude towards joint projects in the countries of the public survey is relatively positive; however, support was significantly higher among respondents in the potential host countries (Spain and Romania) as compared to respondents in the potential off-taker countries (Germany and The Netherlands). The perception of the benefits and costs of the projects and affect play an important role for the support of joint projects.

➡ Specific segments of the population should be more actively engaged in the development of joint projects to increase public support for cooperation in some countries.

➡ Window of opportunity for CSP is a scenario where cooperation across countries in Europe is strengthened more generally (related to strengthen a European Energy Union, but also a stronger European alliance on more general terms where such projects are also seen as important because they contribute to local economic strength and value creation).

3 CONCLUSIONS

Cooperation mechanisms were introduced by the European Commission in 2009 (with Directive 2009/28/EC) to support the EU Member States in reaching their binding 2020 RES target share in an efficient way through collaborative efforts. However, until today, the mechanisms have hardly been used and none of the examples of collaborative renewable energy deployment included CSP projects so far. Within the frame of the MUSTEC project, we have thus analyzed various aspects that affect CSP deployment and the use of cooperation mechanisms for renewable energy technologies in the European Member States to identify the key barriers and drivers for collaborative CSP deployment in the future.

The competitiveness of CSP in the European electricity market crucially depends on the market environment and the future development of techno-economic parameters of CSP projects, in particular the question to which extent the LCOE of CSP can be brought further down in the future. At present, CSP technologies cannot compete with PV or wind onshore plants based on a comparison purely focused on the technologies' LCOE. So far, parabolic trough has been the dominant CSP technology, however, on a global scale significant cost reductions for announced solar tower projects suggest that solar towers might become the front-runner technology in the future.

Besides targeted R&D efforts, one of the most significant levers to lower the LCOE of CSP are the investment costs, which emphasizes the need for targeted financing packages for CSP projects and a generally favorable investment framework that lowers the risks associated with this type of investment intensive, large-scale RE projects. Policy stability and continuity in renewable energy policy also play a major role in this regard and are considered as even more relevant than the actual type of support scheme by many CSP stakeholders.

CSP is one of many technology options that can be deployed to add flexibility to the European electricity system and the competitiveness of CSP depends on a multitude of framework factors which, to a large extent, reflect the strategies and preferences of the individual Member States. This implies that whether there will be a niche for CSP in the European electricity system of the future, depends on a variety of political steps on national and European level, including the strengthening of physical interconnections and the creation of a favorable market design. The main competitive advantage of CSP is the dispatchability of the generated electricity. Thus, to make CSP deployment profitable, ambitious energy and climate policies that set the appropriate price signals and reflect the value of flexibility are crucial. In a market setting, where, in parallel to increased shares of PV and wind in the electricity system, also CO₂ and natural gas prices are rising, a high market value of CSP and high average electricity prices can lead to high revenue levels for CSP and thus allow for the formation of a niche for CSP in the market. However, even though all EU Member States intend to strongly decarbonize their power systems and substantially expand the deployment of intermittent renewable energy technologies, the simultaneous development of flexibility options is still largely underrepresented or missing in the national energy strategies. Towards the 2030 horizon, when

ambitious fossil-fuel phase out decisions are to be realized while ensuring system flexibility, this might support the creation of opportunities for trading dispatchable renewable electricity generated by CSP.

A further factor that has a significant impact on the competitiveness of CSP are geopolitical aspects and here in particular the role of oil and gas in the national and regional energy strategies. National as well as regional energy security strategies should recognize the beneficial role of RES cooperation in general and the opportunities related to CSP in particular. Past experiences with regional energy initiatives have shown that regional cooperation needs to be pushed by the development of concrete regulatory solutions and that the implementation of related pilot projects are a main vehicle for coordinating the practical implementation of the European cross-border regulatory framework. This underlines the importance of strong signals and a clear communication strategy on EU level that emphasizes the relevance of RES cooperation for the European energy market integration.

Against the background of low CSP technology deployment rates in the EU during the past years, also the European CSP industry is facing a transformation. Due to the low inner-European demand for CSP components, the CSP industry has been forced to modify its business models by adding additional services and covering more stages of the CSP value chain as well as by widening their portfolio through moving to other RE technologies. On a global level, previously dominant European companies are being replaced by new, mainly Chinese and other Asian companies. This could eventually lead to a decrease in learning processes, as experienced companies might vanish and innovation networks in which they are integrated might get weaker or even disappear completely.

The EU level policy framework provides the framing and defines the possibilities for RES cooperation projects and the opportunities for CSP projects in the future. For the time horizon 2020-2030, the previous framework for RES cooperation changed in so far as the 'Clean Energy for all Europeans' (CE4ALL) regulatory package defines an EU-wide RES target of 32% but no binding national targets are stipulated anymore. This could provide a stronger basis and impetus for collaborative RES deployment among EU Member States. In addition to the cooperation mechanisms established since 2009, new modes of collaborative RES deployment are now conceivable under the 'enabling framework' and the 'EU financing mechanism', instruments that are supposed to prevent a potential collective delivery gap but are yet to be designed in detail. As an additional instrument that could drive RES collaboration in the future the new 'Connecting Europe Facility' (CEF) now also addresses cross-border RES projects. Financial support under the CEF could thus be relevant for reducing the investment costs for CSP projects.

However, the extent to which CSP projects will benefit from the new measures and instruments in the 2030 policy framework will depend on the individual Member States' interests to engage in RES cooperation and to expand the flexibility of their electricity systems based on CSP (as opposed to other technology solutions such as e.g. storage, increased demand response or sector coupling). Eventually, the uptake and market diffusion of technologies or the use of political instruments, such

as RES cooperation mechanisms, depends on the decisions of various stakeholder groups and their perception of the advantages and disadvantages of the respective technology or instrument. RES cooperation has largely been perceived as highly complex and a large number of barriers for RES cooperation has been identified. Therefore, all relevant stakeholder groups in the technical innovation system of CSP need to be addressed to avoid potential social acceptance issues related to potential CSP cooperation projects in the future.

The heterogeneous and largely ambivalent view on CSP cooperation should be addressed by targeted communication strategies emphasizing the potential benefits of joint renewable energy projects. For CSP projects as such, local acceptance is not a particularly critical issue as the power plants are typically located in more remote areas with a low population density. Furthermore, a positive attitude exists in potential host countries based on the prospect of local economic benefits (i.e. job creation and industry development). However, cooperation in the sense of supporting renewable energy projects in a foreign country based on a national public budget might cause significant acceptance issues - at least these are anticipated by some stakeholder groups, especially policy makers. The current public opinion is more on the positive side; however, as awareness is low, it is likely to be volatile depending on the dominant narrative that comes up in case of actual cooperation projects. Negative framings could be counteracted by strategies that aim for an equal distribution of benefits among potential host and off-taker countries. The general benefits of the creation of a more integrated, European energy system and the positive impacts on regional economic development should be underlined and the general attitude towards the European Union should be addressed to increase public support for collaborative approaches in general.

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WHO WE ARE

The MUSTEC consortium consists of nine renowned institutions from six European countries and includes many of the most prolific researchers in the European energy policy community, with very long track records of research in European and nationally funded energy policy research projects. The project is coordinated by Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas-CIEMAT.

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European Solar Thermal Electricity Association – ESTELA	BE	
COBRA Instalaciones y Servicios S.A – COBRA	ES	
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