Market Uptake of Solar Thermal
Electricity through Cooperation

Roadmap for collaborative CSP development in Europe

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MUSTEC

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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 analyse 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 and the European Green Deal is aiming at climate neutrality until 2050. 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 on the one hand and the ambitious decarbonization goals on the other hand, emphasize the relevance of coordination and collaborative approaches to reach the envisaged renewable energy share and climate neutrality 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 were 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 of this report

Within the MUSTEC project, the aim of this report is to provide a synopsis of the relevant framework conditions for a possible development of CSP cooperation projects in Europe until 2030 and to highlight the crucial steps required to allow for this transition.

In general, a roadmap is a visual medium for communication that presents a long-term vision on a certain development, i.e. a target picture, and a structured overview of the steps towards it (Phaal et al. 2004; Geschka et al. 2008; Möhrle et al. 2013). Thereby, it can help to decompose complex systems into sub-systems and organize different perspectives and strategic aspects relevant to the development in an intuitive graphical representation (Petrick 2008). Important events or achievements in this process are marked as milestones and the roadmap visualizes the impact of the timing and sequence of these events. A roadmap is, however, not meant to be a forecast or a detailed masterplan but rather a tool to visualize and bundle knowledge on potential future developments, to make it easily communicable and to support decision making (cf. Da Costa et al 2005).

Other CSP technology roadmaps, for example, published by the International Energy Agency (IEA 2010, IEA 2014) or NREL (2017) focus mainly on the future technology evolution and the related cost reduction potential of CSP technologies.

In contrast to these technology roadmaps, the roadmap presented in this report aims to illustrate the broader framework conditions which are relevant to allow for CSP development in Europe with a special focus on collaborative project development. It is based on the findings and major lessons learnt on CSP development and RES cooperation in Europe obtained through the analyses carried out in all previous work packages of the MUSTEC project. Some of the main lessons learnt, major barriers and drivers for CSP cooperation projects as well as crucial requirements and issues to be addressed by policy makers (on both EU and national level) have already been summarized in the MUSTEC synthesis report (Boie and Franke 2020) (MUSTEC deliverable 10.1). The roadmap intends to further systematize these findings and is moreover meant to serve as the basis for the more detailed Action Plan (Del Rio and Boie 2021) (MUSTEC deliverable 10.3) which provides in-depth recommendations for specific policy measures for the support of CSP cooperation projects in the EU.

Of course, CSP cooperation projects should be put into the context of the European CSP industry, as they alone cannot sustain this industry. However, they can be a relevant component of an EU-wide CSP development and provide an important guiding framework and provide valuable impulses for the overall evolution of the technology within the European Union and globally.

1.3 Methodology

In line with the overall aim of WP10 to summarize and systematize the crucial requirements and issues for CSP cooperation projects identified in the frame of the MUSTEC project, the roadmap is based on the findings on major barriers, drivers and lessons learnt on CSP development and RES cooperation in Europe obtained through the analyses carried out in the context of all previous work packages. From these major drivers and barriers for CSP cooperation, crucial issues to be addressed by policy makers on European and national level have been identified by the individual work package leaders and were summarized in the WP10 synthesis report (Boie and Franke 2020). Starting from this basis as well as the detailed results described in the previous MUSTEC project reports, the main steps for addressing the identified issues and implementing respective measures were defined and arranged chronologically in the form of a roadmap that illustrates a potential development of the framework for CSP cooperation projects in Europe until 2030.

Thereby, the following steps were performed:

To increase the clarity and readability of the roadmap, the identified **key issues were initially grouped thematically into three layers**, which differentiate major fields of action and respective policy measures ('policy blocks') which are also reflected in the associated Action Plan (MUSTEC D10.3). Naturally, this grouping is partly subjective and the thematic fields can have overlaps and interferences.

For each identified layer, the **roadmap is based on the status quo and refers to the aspired long term goal or target picture**. The status quo, in this context, covers the situation assessed during the MUSTEC project duration (2017-2020) and the target picture refers to 2030, which is the time frame of the analyses and modelling exercises within MUSTEC. After identifying these cornerstones, the **required steps and measures to bridge the identified gap in the framework are defined and arranged in a chronological order** based on the project findings. Particularly important achievements are marked as key milestones (highlighted with a diamond symbol in the graphs). The suggested steps and milestones further **distinguish between the level of responsibility, i.e. measures to be taken by policy makers on EU level and on national level**.

Besides including the **expert input from the project consortium and drawing on the previous project results**, additional feedback was collected from **stakeholders, mainly from the CSP industry sector, through an online questionnaire** assessing the relevance of different potential policy measures and framework conditions for CSP cooperation. In the questionnaire respondents were asked to indicate the relevance of a number of potential measures to support collaborative CSP projects on the following scale:

- Very important → Crucial measure, to be addressed immediately and with high priority
- Moderately important → Lower priority or to be addressed in the longer term
- Not important → No crucial measure

Respondents further had the option to state if they could not judge the importance of a specific measure and were able to provide additional comment or add measures. The input of a number of 33 stakeholders was evaluated for the preparation of this report. A complete overview of the results of the survey is included in the Annex.

On the basis of the above steps, the roadmap provides a synopsis and overview of the key steps to support collaborative CSP development in Europe, however, a more detailed description of the individual measures can be found in a separate document, i.e. the Action Plan (MUSTEC D10.3).

2 Executive Summary

In the past few years, global CSP deployment has slowed down and shifted away from the former front runner countries in Europe and North America. China, Israel and South Africa were the most dynamic markets in 2018/2019. Developments in the upcoming years are also expected in the Middle East and North Africa (MENA) region (IRENA 2020a). Furthermore, Australia and South Africa had planned to develop CSP further (IEA 2020). However, recent trends show a nearly complete standstill in the global CSP project pipeline and several countries abandoned their previous plans for CSP deployment (Liliestam et al 2021). Past market analyses (IEA 2014) projected that, by 2050, CSP could contribute with up to 4500TWh/a, an assumed 11% of the global electricity demand by then, and recent, more optimistic analyses even suggest that CSP could provide up to 25% of the global energy needs by 2050 (Aruvian 2020). Though, based on the latest observations in the global CSP market (cf. Liliestam et al 2021), these projections seem questionable.

Considering the stagnant market growth in the EU during the past years, the European CSP industry is facing severe challenges. Despite of the promising global market projections, the low inner-European demand for CSP components has partly forced the stakeholders of the CSP value chain to modify their business models and to widen their portfolio by moving to other renewable energy technologies (Papadopoulou et al 2019a). There is a concern that this trend could result in the disappearance of many European companies and, eventually, in the dissolution of innovation networks and in the field of CSP.

To provide a transparent and reliable perspective on European CSP development that can sustain a European CSP industry in the long term, an EU-wide strategy for CSP cooperation projects should be embedded in and coordinated with clear and ambitious targets and strategies for CSP deployment on the national level. The role of CSP as a dispatchable renewable energy technology that can add to energy security and help with balancing of energy systems with high shares of fluctuating renewable energy sources needs to be acknowledged, anchored in strategic energy plans and reflected by respective policies that allow for the formation of a niche in the market in which CSP can be competitive with other renewable energy technologies. Collaborative CSP deployment driven by EU Member States could be an important component and contribute in this regard.

The levelized cost of electricity (LCOE) of CSP has seen a clear downward trend in recent years but it needs to be reduced further to make CSP more competitive. Existing CSP projects are still dominated by parabolic trough plants and average LCOE of 0.12 USD/kWh could be observed (Lilliestam 2018), which is still higher than the LCOE of wind and PV (see IRENA 2020b). However, the CSP LCOE trend 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 parabolic troughs. In the latest CSP auctions record breakingly low costs have been announced for solar tower projects, which suggests that solar towers might become the front-runner CSP technology in the future (Lilliestam 2018). Nevertheless, to allow CSP to keep up with other renewable energy technologies and to prevail against balancing, storage and sector coupling technologies, further significant cost reductions are necessary. Besides continued and targeted R&D efforts to enhance the efficiency of CSP power generation, key elements to support this development comprise the creation of a favorable investment framework and the provision of financing tools that help to hedge the risks related to project implementation. For large CSP projects with comparatively high investment volumes and long realization time frames, the cost of capital remains the major cost driver for the produced electricity (Papadopoulou et al. 2019). Against this background, also a stable political framework and continuity in renewable energy policy on both national and European level are particularly crucial factors. Policy stability is considered even more relevant than the actual type of support scheme by many CSP stakeholders.

A further key element that defines whether there will be a niche for CSP in the European power system of the future is the power market structure and the broader market setup. The creation of a favorable market environment that allows for profitable CSP deployment requires ambitious energy and climate policies that set the appropriate price signals and reflect the value of flexibility in the electricity system. In a market setting, where, in parallel to increased shares of PV and wind energy in the electricity system, also CO_2 prices and natural gas prices are rising, a profitable market value of CSP can be achieved which would allow for the formation of a niche for CSP in the market (Welisch 2019; Schöniger und Resch 2019). In this context, CSP should be seen as a complementary technology, rather than a competitor to more established, variable renewable energy technologies like PV and wind energy as it can deliver firm and flexible power and contribute to balancing the electricity system. Concerted actions are required across all EU Member States in this regard, which correspond with clear and binding national targets for the deployment of individual flexibility and sector-coupling options with a clear role defined for CSP.

The European policy framework for renewable energy cooperation in the past has failed to incite relevant developments in cooperative RES deployment and RES development has remained a national matter. Obviously, renewable energy cooperation has to be initiated on national level and driven by national stakeholders and cooperation projects must be embedded in the respective national energy and climate strategy. However, in order to stimulate and facilitate the use of cooperation mechanisms in the field of renewable energy, also a clearer statement and a more targeted supportive framework on EU level are crucial to pave the way for cooperative renewable energy development in the future and to hedge the additional risks and reduce the added complexity of developing renewable energy projects cooperatively across the EU. Since the introduction of renewable energy cooperation mechanisms in 2009 with Directive 2009/28/EC, no significant progress has been achieved in the field of cooperative renewable energy deployment in the EU. Also recent developments of the EU policy framework under the 'CE4ALL' policy package, including the 2018 Recast Renewable Energy Directive 2018/2001 and the Governance Regulation 2018/1999, are unlikely to cause a considerable increase in the use of cooperation mechanisms unless there is a clear push for collaborative renewable energy deployment in the EU such as a mandatory opening of RES support schemes (Essig et al 2019). It is further crucial that the additional complexity of collaborative RES projects is compensated by the further development of an effective supportive regulatory framework and the targeted design and application of instruments under the recast RES Directive 2018/2001 and the efficient use of the available funds for cross-border RES projects under the Connecting Europe Facility (CEF). For CSP in particular, this would imply the creation of technology-specific support, including tenders, which take into account the particular features of this technology and the provision of financing instruments to hedge the risks associated with the implementation of such large-scale projects which naturally involve long lead times and realization periods. Especially the design of the auctions for renewable energy support is crucial to allow for CSP to leverage its strengths and compete against wind and solar PV (i.e. acknowledge the value of dispatchability and storage and provide remuneration that reflects the value of electricity also at peak demand times). To address risks related to cross-border RES projects, the CEF could play a major role in reducing the financing costs for cooperative CSP projects and allow for the implementation of successful lighthouse projects which could serve as positive examples for further cooperative initiatives in the future.

Economic support for CSP through auctions in the EU is not only needed, but very urgent. At the global level, the need for immediate deployment support is related to the potential for cost reductions of the technology with increased deployment (learning curve effects). At the moment, however, the thin global CSP project pipeline prevents the technology to advance along its learning curve as no project broke ground in 2019 and only four projects were under construction in 2020 (Lilliestam et al 2021). The global need for support also implies benefits on global and EU level. As shown by Lilliestam et al (2021), all of the most experienced CSP companies across the most important value chain segments are European. The disappearance of European CSP companies would thus not only imply a loss of jobs, economic benefits and innovation potential in Europe but would also entail a major damage if not the collapse of the global CSP industry.

Public awareness and public acceptance of renewable energy cooperation projects among the Member States of the European Union are still at an early development stage and largely dominated by ambivalence and

skepticism (Dütschke et al 2019). To ensure a broad public support and avoid opposition to future CSP cooperation projects, basic groundwork needs to be done to spread respective narratives and create awareness for the benefits of renewable energy cooperation projects among the general population as well as all other relevant stakeholder groups, such as NGOs or local and national policy makers. In this context, both, the relevance of dispatchable renewable energy technologies in energy systems with high shares of renewables, as well as the potential role of inner-European energy cooperation and advanced market integration as key elements for enhanced energy security, as well as for economic development, need to be included in communication strategies in order to attain a broad public support for cooperation projects in the future. Showcases of successful cross-border CSP cooperation projects and research analyzing their various benefits on national end EU level could contribute significantly to this and should be used progressively to establish a positive mindset towards cooperative renewable energy deployment in general and towards CSP projects in particular.

3 Potential role of CSP cooperation projects in the European energy system of the future

Over the past decade the global installed capacities of Concentrated Solar Power have increased continuously and reached almost 6.3 GW in 2019 (cf. Table 1). However, during the past few years, CSP deployment has shifted away from the former pioneers and front runner countries in Europe and North America, i.e. Spain and the USA. Instead, the strongest market growth in recent years could be observed in China, Israel and South Africa as well as in Morocco, Saudi Arabia and Kuwait (cf. Table 1). Further developments in the upcoming years are expected in the Middle East and North Africa (MENA) region and also Australia plans to extend its CSP capacities further (IRENA 2020a, IEA 2020). However, recent trends show a nearly complete standstill in the global CSP project pipeline and several countries abandoned their previous plans for CSP deployment (Liliestam et al 2021) so it is questionable whether the expected developments are actually going to materialize.

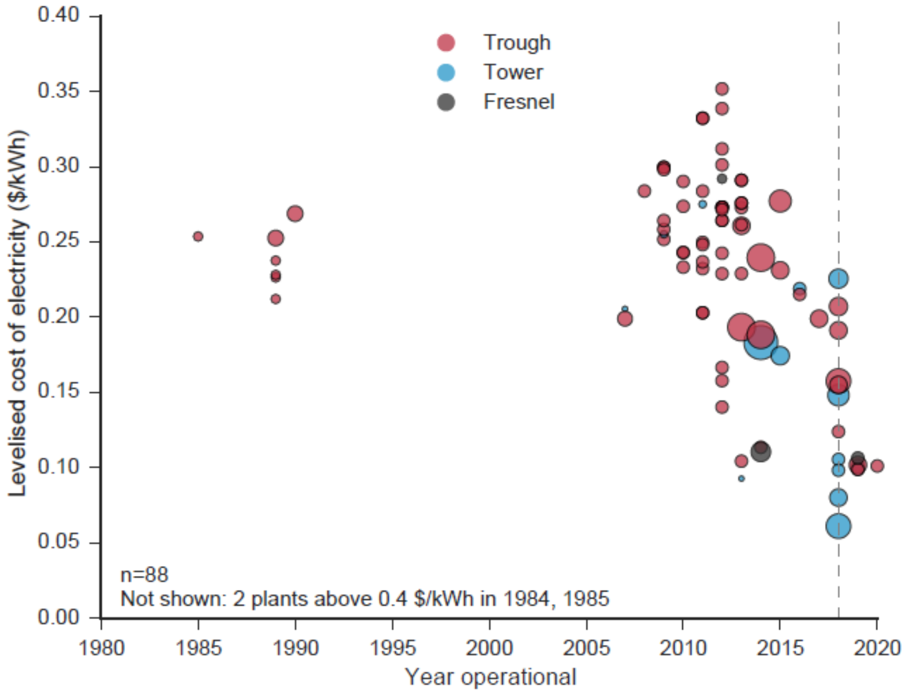
Table 1: Global cumulated installed CSP capacities 2010-2019 by country. The symbols indicate capacity changes compared to the previous year.

		2010	2012	2013	2014	2015	2016	2017	2018	2019
Algeria	25	25	25	25	25	25	25	25	25	25
Egypt	0	20	20	20	20	20	20	20	21	21
Morocco	20	20	20	20	20	180	180	180	530	530
South Africa	0	0	0	0	100	100	200	300	400	500
Israel	6	6	6	6	6	6	6	6	6	248
Kuwait	0	0	0	0	0	0	0	0	0	50
Saudi Arabia	0	0	0	0	0	0	0	0	50	50
UAE	0	0	0	100	100	100	100	100	100	100
China	0	0	1	11	11	11	21	21	271	421
India	0	3	4	54	229	229	229	229	229	229
Thailand	0	0	5	5	5	5	5	5	5	5
France	0	0	0	0	0	0	0	0	0	9
Germany	2	2	2	2	2	2	2	2	2	2
Italy	5	5	5	5	6	6	6	6	6	6
Portugal	0	0	0	0	0	0	9	14	14	14
Spain	732	1149	2000	2304	2304	2304	2304	2304	2304	2304
Turkey	0	0	0	1	1	1	1	1	1	1
USA	473	472	476	1286	1667	1758	1758	1758	1758	1758
Mexio	0	0	0	0	0	0	0	0	14	14
Australia	3	3	3	3	3	3	3	2	2	2
Total	**1266**	**1705**	**2567**	**3842**	**4499**	**4750**	**4869**	**4973**	**5738**	**6289**

Source: based on IRENA (2020a)

A changing dynamic could also be observed regarding the generation costs (i.e. the Levelized Cost of Electricity, LCOE) for different types of CSP technologies. Figure 1 illustrates the dynamic of the LCOE of existing CSP projects and projects under construction (by 2019) distinguished by the type of CSP technology (parabolic trough, solar tower and Fresnel). The strongest cost decline can be observed for solar towers, however, also the costs for the so far most common parabolic trough technology have been dropping further (Lilliestam 2018). Depending on the further cost development, this could lead to a dynamic of solar towers replacing parabolic troughs as the leading technology in the future.

Global market analyses by the International Energy Agency (IEA) in 2014 (IEA 2014) projected that by 2050 CSP could contribute with up to 4500 TWh/a, an assumed 11% of the worldwide electricity demand by then, and recent, even more optimistic analyses even suggest that CSP could provide up to 25% of the global energy needs by 2050 (Aruvian 2020). Even though, reflected against the latest deployment rates, these numbers seem overly optimistic, the prospects for the combination of CSP with water desalination technologies in arid climates as well as the possibilities to use CSP for the production of green hydrogen (see eg. Boudries (2017)), for example, for fuel cells imply vast opportunities for the global deployment of CSP in the future.



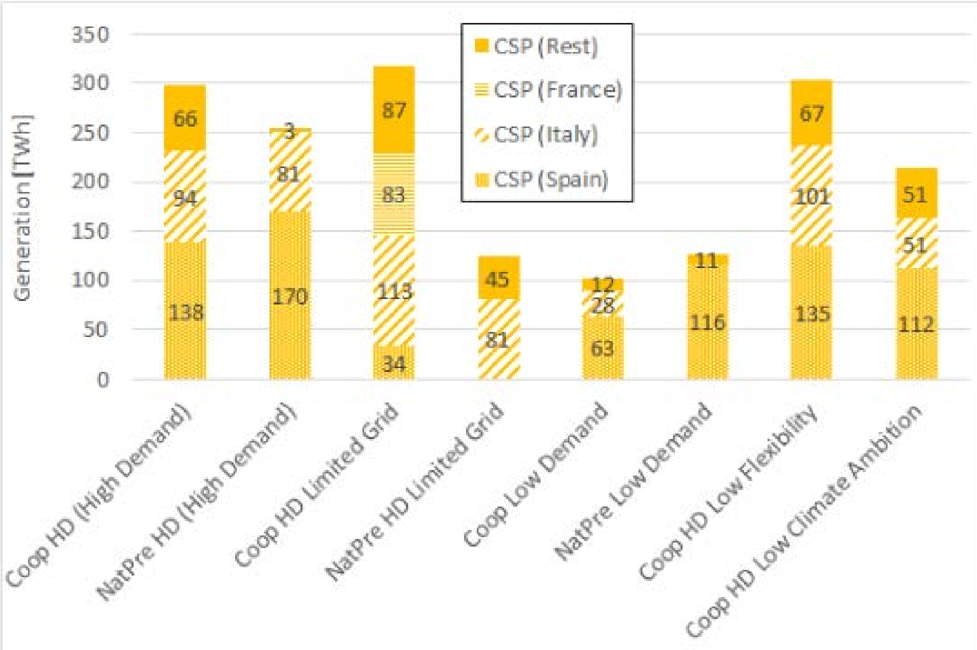
SOURCE: (LILLIESTAM 2018)

Figure 1: Analysis of the LCOE of CSP plants (past and present) and those under construction differentiated by technology type (excl. hybrid plants)

However, the global CSP deployment trends (cf. Table 1) clearly show that this development is recently shifting away from Europe and that the CSP markets in Europe have become nearly stagnant. This dynamic confronts the previously dominant European CSP industry with severe challenges as Chinese and other Asian companies were advancing in the global business (Lilliestam 2018). Despite of the potential global market development, the low inner-European demand for CSP components seems to have partly forced the European CSP industry stakeholders to modify their business models and to widen their portfolios by moving to other services and other renewable energy technologies (Papadopoulou et al. 2019a). Eventually, this trend could result in the disappearance of many European CSP companies, with the associated loss of jobs and economic development opportunities and the dissolution of long-standing innovation networks in the field of CSP.

The European targets for the reduction of greenhouse gas emissions by 2030 by at least 40% and the increase of the share of renewable energies to at least 32%, as defined by the 'Clean Energy for all Europeans' (CE4ALL) regulatory package, as well as the long-term goal of reaching climate neutrality by 2050, have set important standards for the energy transition on EU-level. With rising shares of fluctuating renewable energy sources like wind and PV in the European energy system, flexibility options such as dispatchable renewable energy technologies and storage technologies, as well as options for sector coupling, are gaining more and more importance to guarantee a reliable and secure energy supply. In this context, CSP combined with storage could be one important component of the portfolio of climate-friendly flexibility options in the future European energy system (Welisch 2019). Model-based scenario analyses carried out in the frame of MUSTEC (see Figure 2) show that, depending on the scenario assumptions, CSP plays a varying though always a relevant role in the European electricity system in 2050 (Resch et al 2020). These findings emphasize that a long-term support strategy is required to ensure that the technology will be available to contribute to the EU energy system when it is needed.

Despite the absence of binding national RES targets for 2030 under the 'CE4ALL' framework, all EU Member States intend to strongly decarbonize their power systems and expand the deployment of renewable energy technologies, however, the required development of flexibility options is still largely underrepresented in the national energy strategies (Lilliestam et al 2019). Against this background, while ensuring system flexibility and security of supply, the realization of ambitious fossil-fuel phase out decisions could open up a relevant niche for the deployment and trading of dispatchable renewable electricity generated by CSP. Modelling results show that, in a market setting with ambitious CO_2 reduction goals, rising natural gas prices and increasing shares of PV and wind, CSP plants with storage could provide a relevant contribution to balancing the energy system by providing CO_2-free, dispatchable electricity (Schöniger and Resch 2019; Schöniger et al. 2020).



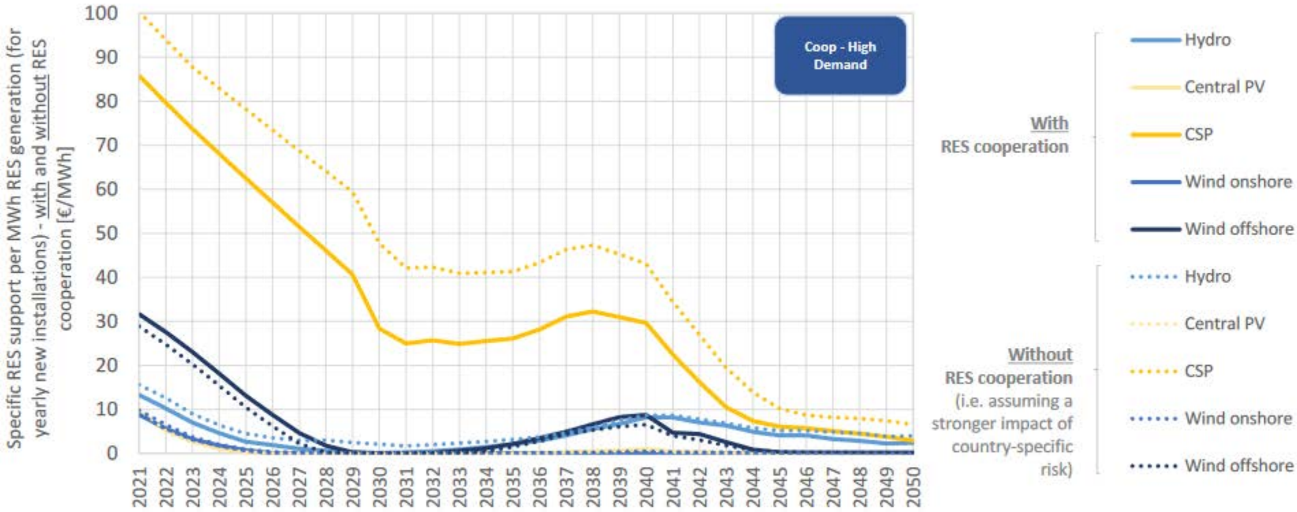
SOURCE: RESCH ET AL (2020)
Figure 2 Electricity generation (TWh) from CSP in the EU in 2050

Also against the background of the geopolitical context and strategies for energy security and reducing the dependency on oil and gas imports to the European Union, more attention could be turned towards the deployment of CSP as a dispatchable and fossil-fuel independent generation technology (Escribano et al. 2019).

Renewable energy cooperation mechanisms were introduced by the European Commission already in 2009 (with Directive 2009/28/EC) to provide the EU Member States with an additional option for reaching their binding 2020 renewable energy target share. In the past, the suggested cooperation mechanisms have hardly been used though, as they were largely perceived as too complex and risky in relation to their potential benefits (Caldes et al 2018; Caldes et al 2019; Oltra et al 2019).

However, the absence of binding national targets for renewable energy deployment by 2030 under the 'CE4ALL' framework could now provide a much stronger impetus for collaborative approaches for the European Member States. In case of a delivery gap towards the common European 2030 target, the CE4ALL' regulatory package offers new modes for collaboration and foresees new instruments and funds to support cross-border renewable energy project development which could be highly relevant also for CSP cooperation projects (Essig et al 2019).

Analyses of the in MUSTEC (cf. Resch et al 2020) show that cooperative approaches in RES development could entail significant cost benefits, i.e. lower specific support costs for various RES technologies, in the long-term. This is illustrated in Figure 3, which compares the future development of the specific support for RES generation until 2050 for two scenarios with and without cooperation, whereby in the scenario without cooperation higher country-specific risk factors lead to significantly higher overall support RES costs. This implies that economic benefits could be achieved through cooperation, not only by reducing LCOE by advancing further on the learning curve through steady technology deployment, but also by exploiting the benefits of collaborative RES deployment and creating a favorable and level playing field for the efficient development of RES technologies across the EU Member States.



SOURCE: RESCH ET AL (2020)

Figure 3 Development of the specific support per MWh RES generation up to 2050 - EU averages for different technologies under different scenarios.

4 KEY ACTIONS TO SUPPORT CSP COOPERATION IN EUROPE

To address the identified key issues and barriers to collaborative CSP deployment in Europe, we have distinguished three main fields of action that need to be addressed by policy makers on European and national level in order to allow for the formation of a niche for the development of CSP cooperation projects in Europe. These are as follows:

- **Political and regulatory framework:** Definition of ambitious and technology-specific goals, provision of targeted support and creation of a suitable market design that recognizes the value of CSP as a dispatchable renewable energy technology
- **Techno-economic framework:** Enhancing the competitiveness of CSP by further reducing the LCOE, effectively hedging project implementation risks and facilitating project financing
- **Socio-political framework:** Creating a broad public acceptance and awareness for the benefits of CSP and the importance of collaborative European approaches for renewable energy support and establishment of the respective political narratives

As mentioned before, this grouping naturally implies overlaps and interferences between the individual policy fields but is deemed to provide a suitable structure for the identified measures. The individual key steps under each of the fields of action are discussed in the following sections. Each section is followed by a graph summarizing the key steps. Possible measures are mentioned and a detailed discussion of these measures is provided in a separate document (i.e. the Action Plan).

4.1 Political and regulatory framework

- ***Definition of ambitious and technology-specific goals, provision of targeted support and creation of a suitable market design that recognizes the value of CSP as a dispatchable renewable energy technology.***

CSP deployment in Europe has come to a near standstill in the past years (cf. Table 1), leaving the European CSP industry with a dark perspective on the future role of CSP in the European energy system and the challenge to sustain its business with uncertain prospects and a simultaneously growing global competition, especially from Asian companies. And even on a global level, CSP deployment has recently slowed down significantly and planned projects have been abandoned, which paints an even darker picture for the future (cf. Lilliestam 2020). Against this background, economic support for CSP in the EU is not only needed, but crucial and urgent. At the global level, the need for immediate deployment support is related to the potential for cost reductions of the technology with increased deployment (learning curve effects). At the moment, however, the stagnation in the global CSP project pipeline prevents the technology to advance along its learning curve as no project broke ground in 2019 and only four projects were under construction in 2020 (Lilliestam et al 2021). The global need for support also implies benefits on global and EU level. As shown by Lilliestam et al (2021), all of the most experienced CSP companies across the most important value chain segments are European. The disappearance of European CSP companies would thus not only imply a loss of jobs, economic benefits and innovation potential in Europe but would also entail a major damage, if not the collapse, of the global CSP industry.

CSP as a dispatchable, carbon neutral technology is only one of various technology options, such as storage and sector coupling technologies that can be deployed to add flexibility to the European electricity system of the future. Whether there will be a niche for CSP thus depends first and foremost on the focus of the national energy strategies and targets and the creation of a favorable market design that allows CSP to play out its value as a dispatchable renewable energy technology. However, the energy strategies of the EU Member States currently do not sufficiently reflect the value of dispatchable renewable energy technologies such as CSP and storage technologies and their potential role in enhancing energy security and balancing of energy systems with high shares of fluctuating renewable energy sources (Lilliestam et al 2019). Spain, Portugal, Italy, Greece and Cyprus have defined targets for the deployment of CSP in their integrated national energy and climate plans (NECPs) but no plans for cooperative CSP projects exist so far in any of the EU Member States (Essig et al 2019). Apart from Spain with a target of 7.3 GW installed capacity by 2030, the Member States' CSP targets suggest a rather moderate deployment of CSP in Europe that will likely not suffice to sustain the European CSP industry based on their present business models (Essig et al 2019).

Also, the role of renewable energy cooperation for regional energy security and system stability is still not adequately reflected in the current plans and measures for the support of renewable energy and largely overshadowed by fossil fuel geopolitics (Escribano et al. 2019). Although the EU regulations under the Clean Energy for All 'CE4ALL' regulatory package, with the 'Recast Renewable Energy Directive 2018/2001' and the Governance Regulation 2018/1999' and the collective European RES target of 32%, emphasize the importance of cooperative approaches for RES deployment and suggest various mechanisms under which cooperative renewable energy deployment could take place, they currently do not create effective incentives for the actual application of these mechanisms (Essig et al 2019). Just as the cooperation mechanisms established by the European Commission in 2009 (with Directive 2009/28/EC) have hardly been applied due to the perceived complexity and risk and the lack of socio-political acceptance, cooperative renewable energy deployment will likely remain irrelevant if no strong incentives are created for its practical implementation.

In order to provide a transparent and reliable perspective on European CSP development that can sustain a European CSP industry in the long term, clear and ambitious long-term targets and strategies for CSP deployment on national level (reflected in reliable, long-term support schemes) are required which should, however, be integrated with an EU-wide strategy for CSP cooperation projects. A clearer statement and a more targeted supportive framework on EU level will be crucial to pave the way for cooperative CSP development in the future and to hedge the additional risks and reduce the added complexity of developing RES projects cooperatively. To allow for the formation of a niche in the market in which CSP can be competitive with other RES technologies, CSP needs to be addressed specifically by renewable energy support and cooperation policies and its role as a dispatchable renewable energy technology that can add to energy security and system balancing needs to be acknowledged more. The high relevance of clear statements and goals has also been confirmed by industry stakeholders participating in the online survey (cf. Figure 6 in the Annex).

The strongest push for collaborative renewable energy and CSP deployment on EU level in the mid- and long-term would be the mandatory opening of renewable energy support schemes as suggested in RES Directive (2018/2001) (Art. 5). In 2023, the European Commission will consider the introduction of an obligatory share of RES supported under the national support schemes of the Member States that has to be open for the participation of other Member States. So far, the opening of support schemes is optional but indicative mandatory shares of at least 5% for 2023-2026 and 10% for 2027-2030, depending on the level of interconnectivity (as physical transfer of electricity might be required), are suggested. This step would create a strong impetus and would be a major milestone for RES cooperation, as it would force the Member States to integrate collaborative RES deployment into their national energy and climate strategies.

However, prior to such mandatory measures, it is crucial to create a framework that reduces the complexity of collaborative renewable energy deployment and to strengthen the infrastructure to facilitate the practical implementation of collaborative projects. The introduction of the 'Union renewable development platform' ('URDP') for facilitated statistical transfers (as defined in Art. 8 of RES Directive 2018/2001 will likely not affect collaborative CSP deployment much, as under a virtual transfer agreement CSP would not be able to play out its competitive advantages as a dispatchable generation technology that can provide balancing services since, in this context, physical transfers would be required. In this regard, support provided through the Connecting Europe Facility (CEF) (see European Commission (2018)) could be relevant as it provides funding for strategic cross-border transmission infrastructure and, from 2021 on, also for cross-border renewable energy projects ('c-b projects in RES') that promote the European energy transition. Under the CEF, cross-border CSP projects could receive grants covering up to 50% of the costs and/or funding for feasibility studies (see also section 5.2). A key milestone in this context would be if, in the timeframe 2021-2027 at least one CSP project would receive funding under the CEF. To provide a clear long-term perspective on the relevance of this instrument, it is further crucial that the European Commission gives a clear indication on the available funds in the period after 2027. In this regard, a binding statement on the future development of the 'c-b projects in RES' program and the funds available for cross-border RES projects should be made in the near to mid-term to allow project developers to plan accordingly.

Further, the establishment of the 'enabling framework' as defined by the recast RES Directive 2018/2001 (Art. 3(5)) could be a key element for collaborative CSP projects. This instrument stipulates the use of Union funds and additional funds, for activities aiming at:

- The reduction of the cost of capital for renewable energy projects;
- The implementation of projects and programs for the enhanced integration of renewable sources into the energy system and to increase system flexibility;
- The development of the electricity grid including storage facilities and other grid related actions to reach the 15 % electricity interconnection target by 2030;
- The promotion of cooperation between Member States or Member States and third countries through joint projects, joint support schemes and opening of support schemes for RES deployment.

As these measures explicitly address the support of projects that can contribute to increasing system flexibility as well as storage options and cooperation projects, they could be of high relevance to cross-border CSP projects. The implemented measures should thus specifically address CSP and should be integrated with European and national measures and strategies for CSP deployment.

With the EU-wide binding 32% RES target for 2030 and the absence of binding national RES targets in the post-2020 framework, the 'renewable energy financing mechanism' which was introduced by the Governance Regulation 2018/1999 (Art. 33) and which will be established by January 2021, has become the central element on EU level to fill a potential future delivery gap between the actual and the envisioned RES deployment pathway and to support collaborative RES deployment. The provided support will be based on EU-wide competitive tenders whereby the support will be granted in form of feed-in premiums on top of the market prices to the bidder offering the lowest costs. Member States can chose to participate in the mechanism, e.g. to reduce their overall RES support costs, while host countries could benefit from additional employment effects. Also irrespective of a delivery gap, the financing mechanism, in combination with the enabling framework, could become a key instrument to promote collaborative RES and CSP deployment, through provision of low-interest loans, grants, or a mix of both to joint projects between Member States (as well as joint projects with third countries). However, to allow for CSP to be competitive in auctions under the EU financing mechanism, tenders would have to be technology-specific and the tender design needs to recognize the value of CSP to allow for CSP to leverage its strengths and compete against lower cost technologies like wind and solar PV, e.g. by acknowledging the value of dispatchability and storage and providing remuneration that reflects the value of electricity at peak demand times (cf. (del Rio & Mir-Artigues 2019)). Key milestones for the implementation of the financing mechanism in this regard would be the submission of binding commitments by participating Member States (potential host- and receiving countries) in the course of 2022 and the organization of first auctions, including an auction specifically targeting CSP, in the timeframe 2023/2024. The collaborative CSP project would be further supported through provision of grants for the feasibility study. Complementary support could be provided to the project under the CEF (see above).

A further key element that defines whether there will be a niche for CSP in the European power system of the future is the power market structure and the broader market setup**.** The creation of a favorable market environment that allows for profitable CSP deployment requires ambitious energy and climate policies that set the appropriate price signals and reflect the value of flexibility in the electricity system. In a market setting, where, in parallel to increased shares of PV and wind energy in the electricity system, also CO_2 prices and natural gas prices are rising, CSP can compete in the market. The results of a case study in Spain show that, with substantial increases of the CO_2 price (above 83€/t), the CSP market value exceeded the electricity price and CSP would play a relevant role in the system while complementing variable RES technologies like PV and wind energy (Schöniger, F., Resch, G. 2019). Also modelling results on European level show that ambitious decarbonisation targets associated with a higher electricity demand, e.g. through intense electrification of the transport sector, can make CSP a viable technology option in the European energy system (Resch et al 2020). In this context, CSP with its firm and flexible power generation should not be seen as a competitor to these more established technologies but as a synergetic counterpart. Concerted actions are required across all EU Member States in this regard, which correspond with clear and binding national targets for the deployment of individual flexibility and sector-coupling options.

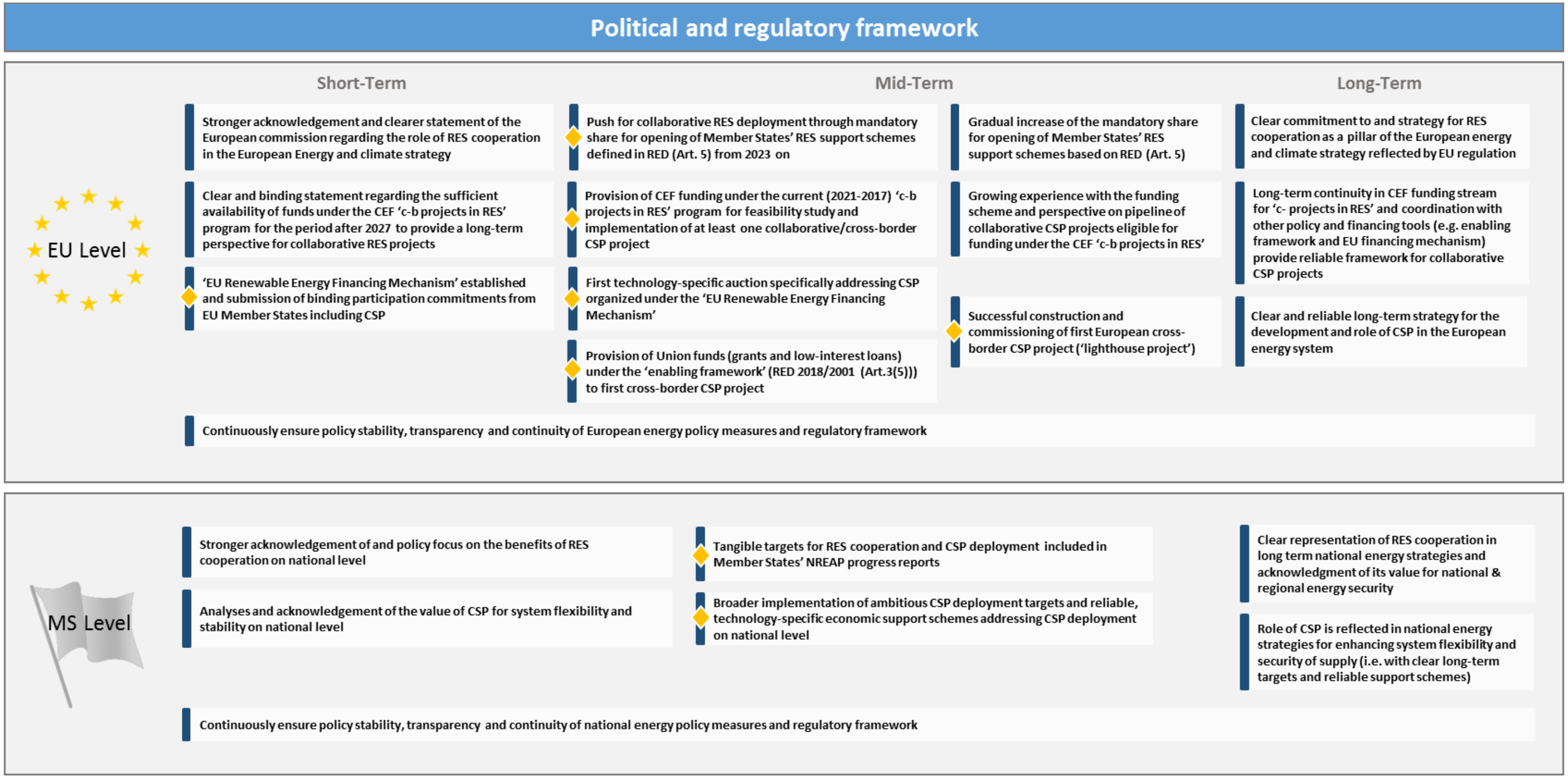


Figure 4: Steps to improve the political and regulatory framework for collaborative CSP deployment in Europe (key milestones marked with diamond)

4.2 Techno-economic framework

ü ***Enhancing the competitiveness of CSP by further reducing the LCOE, effectively hedging project implementation risks and facilitating project financing.***

The levelized cost of electricity (LCOE) of CSP has decreased significantly over the past decade (cf. Figure 1). However, with an average LCOE of 0.12 USD/kWh, CSP is still not competitive with PV and onshore wind on a purely economic level. Besides the cost of the technology itself, the financing costs for large CSP projects with comparatively high investment volumes and long realization time frames play a major role in the resulting LCOE (Papadopoulou et al. 2019b) and are thus a key lever that needs to be addressed by the support framework.

When looking at the globally installed capacity, the dominant CSP technology is still parabolic trough but, since 2018, the costs of solar towers have been declining even faster than those of solar troughs. Latest CSP auction results with record-breakingly low generation costs suggest that in the future, solar towers might become the new front-runner technology (Lilliestam et al. 2018). Larger plant sizes and larger thermal storage capacities sizes in recent projects also helped to bring LCOE further down (Lilliestam et al. 2018). Thermal storage is a comparatively inexpensive form of energy storage, which is already competitive for longer storage durations today. Thus, by including CSP more explicitly in the European energy strategy, Europe would also allow for this storage solution to contribute to balancing the European energy system.

However, there is no clear and reliable perspective on the inner-European CSP development today that could sustain a European CSP industry in the long term. To allow CSP to compete in the EU energy and innovation landscape of the future, and to enable the technology to find a niche among other generation, balancing, sector coupling and storage technologies, it is crucial to take measures to achieve further significant cost reductions through continued R&D activities and by setting up a favorable economic framework for the realization of CSP projects. Industry stakeholders participating in the online survey reported that there is a severe shortage of funding for R&D activities, both on national and EU level, and that they miss a focus on CSP in the European R&D strategy.

To address these issues, an EU-wide strategy for CSP development in general, and the application of CSP in cooperation projects in particular, should be developed and embedded in and coordinated with clear and ambitious targets and a suitable market design for CSP deployment on national level (cf. section 5.1). In this regard, CSP should be addressed more explicitly in the European energy technology research strategy, for example, reflected by a continued and stronger embedding of CSP under the European Strategic Energy technology Plan (SET Plan) and the related innovation platforms and research alliances (like e.g. the 'CSP/STE Implementation Plan'). On this basis, targeted financial support for R&D activities on both European and national levels needs to be directed especially to CSP demonstration projects, which was rated as the highest priority (very important) by the majority of the industry stakeholders participating in the online survey (cf. Figure 7 in the Annex). Further, more financial support in the form of loans and grants should be directed to research activities in private and public research institutions in the field of CSP and to investigate the benefits of cooperative renewable energy deployment. Research activities that should be addressed with priority include efforts to enhance the efficiency of CSP power generation to further reduce LCOE and research on innovative approaches, such as possibilities to combine CSP with hydrogen production. Also technology combinations with other renewable energy generation technologies, such as PV or biomass, could be investigated further to assess potential benefits from technology hybridization.

Another possible support measure, but seen as a lower priority by CSP stakeholders (cf. Figure 7 in the Annex), is the financial support for solar potential (i.e. DNI) measurements to facilitate feasibility studies for future CSP projects.

Besides funding of CSP research activities under national and European research programs, the 'enabling framework' as defined by Art. 3(5) of the recast RES Directive 2018/2001 is one more element that could contribute significantly to a more favorable economic framework for CSP cooperation projects (see also section 5.1). The enabling framework aims at supporting the EU Member States in realizing ambitious renewable energy deployment and decarbonisation strategies to ensure that the binding 2030 RES target on EU level is reached. Thereby the framework intends to addresses in particular technologies that help to increase system flexibility, cross-border interconnections, storage technologies and cooperative RES deployment approaches (cf. section 5.1). Even though the actual implementation of these activities is not yet defined, all of the above could be of direct relevance to CSP cooperation projects as CSP projects could help to increase the flexibility of the European electricity system by providing dispatchable renewable electricity combined with storage. Further, as the enabling framework explicitly foresees the enhancement of regional cooperation and joint projects in renewable energy, CSP cooperation projects should be one focus area of the support activities and specifically targeted in the design of the implemented measures. Dedicated funding streams under the enabling framework should be earmarked for the enhancement of the financing conditions for CSP, e.g. by providing low interest loans or grants for feasibility studies, DNI measurements and the implementation of cooperative CSP projects.

Complementary to financial support provided under the EU enabling framework, also the new financing stream under the Connecting Europe Facility (CEF) addressing cross-border projects in the field of renewable energy (c-b projects in RES) can be a key instrument that could contribute to enhancing the economic framework for CSP cooperation projects in the medium to long-term. Between 2021 and 2027, a budget of 8.7 billion Euro is foreseen under the CEF to support the European clean energy transition. In this context, up to 50% of the costs for renewable energy cooperation projects between two EU Member States or Member States and third countries can be provided if they can demonstrate that they provide an EU added value and the existence of a funding gap. Cooperative CSP projects between two EU Member States could consequently receive funding under the CEF if the implementation of the project would lead to cost savings or offer benefits with respect to system integration, security of supply or innovation. The CEF supports preoperational or feasibility studies as well as construction of the plant and could thereby contribute significantly to the reduction of the resulting LCOE of the power plant. However, in light of the limited budget and time-frame of the program and due to the likely competition with other technologies, it will most likely only make a minor contribution to the development of CSP in Europe.

However, a major milestone for collaborative CSP deployment would be reached if at least one cross-border CSP project would receive financing under the CEF in the specified time-frame (2021-2027). For example, Navigant and Ernst & Young (2019), who developed an evaluation framework for potential cb-RES projects applying for funding under the CEF, suggested that a potential joint CSP project between Germany and Portugal could be eligible and funded with 25million Euro with the pre-feasibility study between 2020-2021, permitting and design of the project in 2022 and construction of the plant until 2025. Another conceivable option would be a joint project, for example, between Spain and Germany, as suggested by Essig et al (2019). A successful joint project that can demonstrate the added value of collaborative CSP deployment in the European energy system could provide a major push for innovation and learning in the field of collaborative RES development and for the public acceptance of collaboration projects in the field of renewable energy in general and CSP in particular (cf. section 5.3).

Another important field of action refers to measures to hedge CSP project implementation risks, as these are a major factor for the cost of finance which, again, is a significant driver for the LCOE. This has also been mentioned as a key measure by respondents of the online survey (cf. Figure 7 in the Annex). In this context, a stable political framework and continuity in renewable energy policy, both on national and EU level, are particularly crucial for investment security, as only a stable policy framework can provide a secure environment for large-scale investments. Further relevant measures in this regard include, for example, facilitation of DNI measurements, simplification of grid access and administrative procedures or the adjustment of time-frames for project realization in auction procedures to reduce project implementation risks and thereby help reducing the cost of capital (cf. section 5.1).

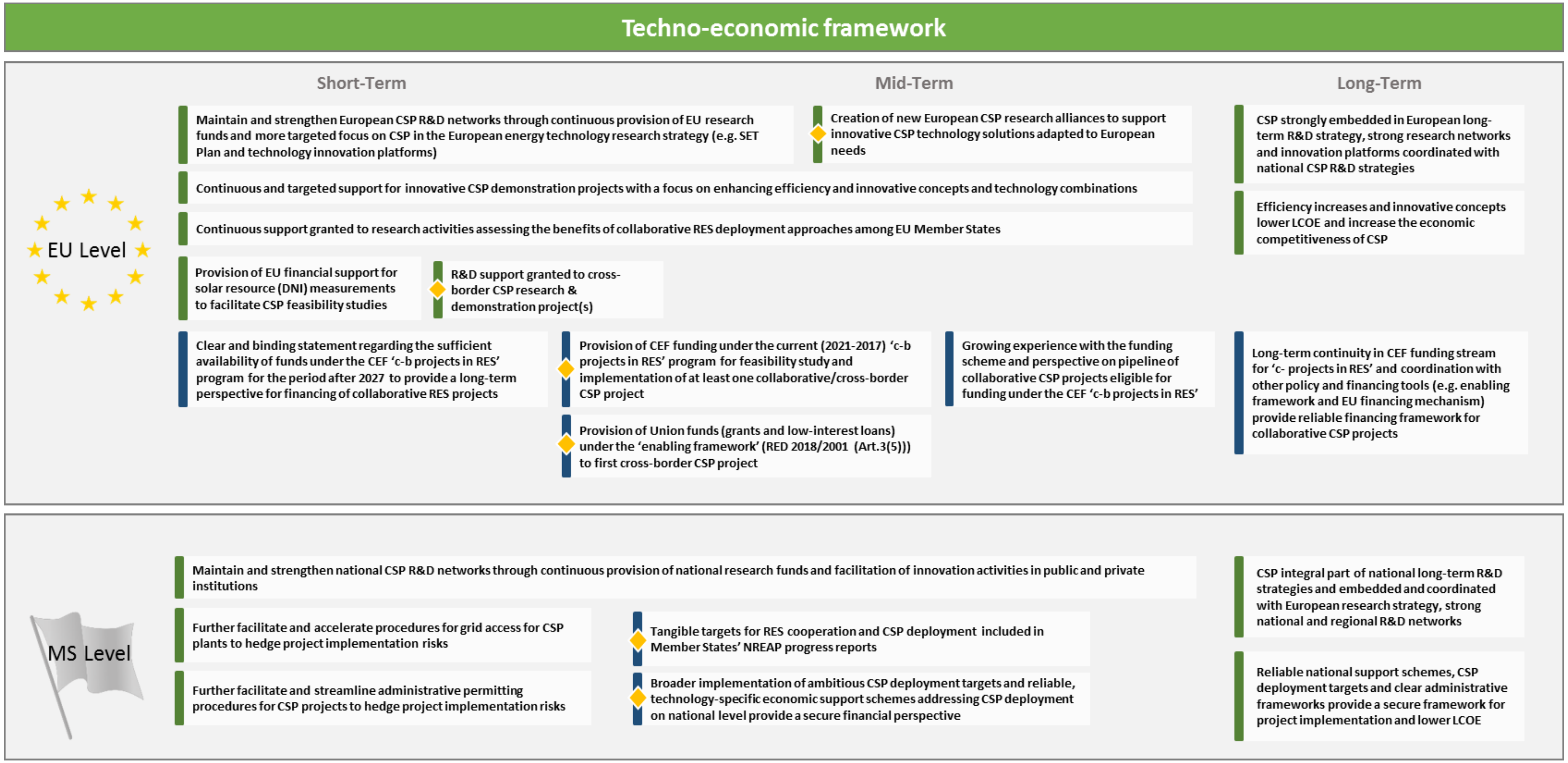


Figure 5: Steps to improve the techno-economic framework for collaborative CSP deployment in Europe (key milestones marked with diamond)

4.3 Socio-political framework

ü *Creating a broad public acceptance and awareness for the benefits of CSP and the importance of collaborative European approaches for renewable energy support and establishment of the respective political narratives.*

The awareness of and public support for renewable energy cooperation projects in the EU Member States is currently still low. Stakeholders from the policy and energy sector, as well as the general public are still mostly ambivalent or skeptical regarding collaborative approaches for renewable energy deployment (Dütschke et al. 2019). Even though most stakeholders admit that, in general, renewable energy cooperation is a positive option to mitigate climate change and to support European market integration, skepticism about the regulatory complexity as well as concerns regarding the spending of tax-payers money on renewable energy projects in other Member States prevail and interest and impetus from actors in the innovation system is missing (Dütschke et al. (2019).

However, a broad social acceptance is crucial to ensure the success of renewable energy cooperation projects and the long-term sustainability of cooperation policies and to avoid opposition to future CSP cooperation projects. Therefore, it is important to address these issues, both in potential electricity off-taker countries and in the regions affected by the construction of the power plants or associated transmission lines.

To lay the basic foundation for a broad public support for CSP cooperation projects in the future, national and European strategic plans and political narratives should emphasize the relevance of dispatchable renewable energy technologies in energy systems with high shares of renewables, and underline the role of inner-European energy cooperation and advanced market integration as key elements for enhanced energy security and the European goal of climate neutrality. In this context, a clearer statement from the European Commission regarding the role of CSP in the European energy system (cf. section 5.1) would be crucial to direct the attention of market players, as well as the awareness of the general public, towards CSP. This has also been emphasized by industry stakeholders who responded to the online survey. They mentioned this as one of the most crucial measures (cf. Figure 8 in the Annex). Another very important measure in this regard is to investigate and address the role of collaborative approaches in the context of European economic development (e.g. through levelling out of country risk premiums, exploiting cost advantages, enhancing innovation effects, etc.) more proactively and to assess and communicate the positive impacts on regional economic development and job creation. This would support a more positive attitude towards an EU-level approach and policy interventions at this level.

Further, all relevant stakeholder groups, such as local and national policy stakeholders, NGOs, the industry and the general public in, both, potential host countries and off-taker countries, need to be addressed by targeted communication campaigns.

In the potential host countries of CSP cooperation projects, the attitude towards the possible CSP projects is generally more positive, as local economic benefits through job creation and opportunities for the local industry and innovation networks can be expected (Lilliestam 2018, del Río and Kiefer 2019, Banacloche et al 2020). Also, community acceptance, i.e. the acceptance in the regions directly affected by the projects, is usually not a highly critical issue for CSP, as the power plants are typically located in remote areas with a low population density. However, it is still important to develop and establish transparent procedures for stakeholder participation in order to be able to understand and address local needs and to avoid local resistance against potential cross-border projects. To provide a sound basis for CSP (and other RES) cooperation projects in the future, these processes should be clearly defined and should follow common EU guidelines to ensure a maximum transparency and to avoid market distortions. In this regard, the provision of best practice guidelines by the EU Commission would be a key milestone in the short-term.

In the off-taker countries, on the other hand, more targeted communication is required to establish public acceptance for the collaborative support of renewable energy deployment across borders. Negative framings relating to public money being spent on economic development in other Member States should be counteracted early on through strategies that aim for an equal distribution of benefits among potential host and off-taker countries and by stressing the relevance of collaborative approaches against the background of growing European market integration. Also in this regard, European guidelines and best practices for the sharing of costs, benefits and responsibilities would be an important first step to avoid negative associations or perceptions of being disadvantaged.

In the mid- and long-term, showcases of first successful collaborative CSP plants or cross-border research and demonstration projects and the associated benefits on national end EU level (i.e. job creation, economic effects, contribution to combat climate change, innovation effects, etc.) should be communicated proactively to further establish a positive mindset towards cooperative renewable energy deployment in general and towards CSP in particular. Such first successful projects, if used for communication thoughtfully and proactively, could be a key milestone for the social acceptance of cooperative CSP projects.

Also in the mid to long-term, encouraging and supporting the implementation of community-driven CSP projects could further help to increase the local acceptance in host countries. This could be achieved by facilitating administrative procedures on national level, providing targeted financial tools on national level and/or facilitating access to European financing schemes. In the long-term, R&D efforts could also be directed to innovative CSP concepts with lesser space requirements and a lower visual impact, which might further help to enhance local acceptance for CSP projects.

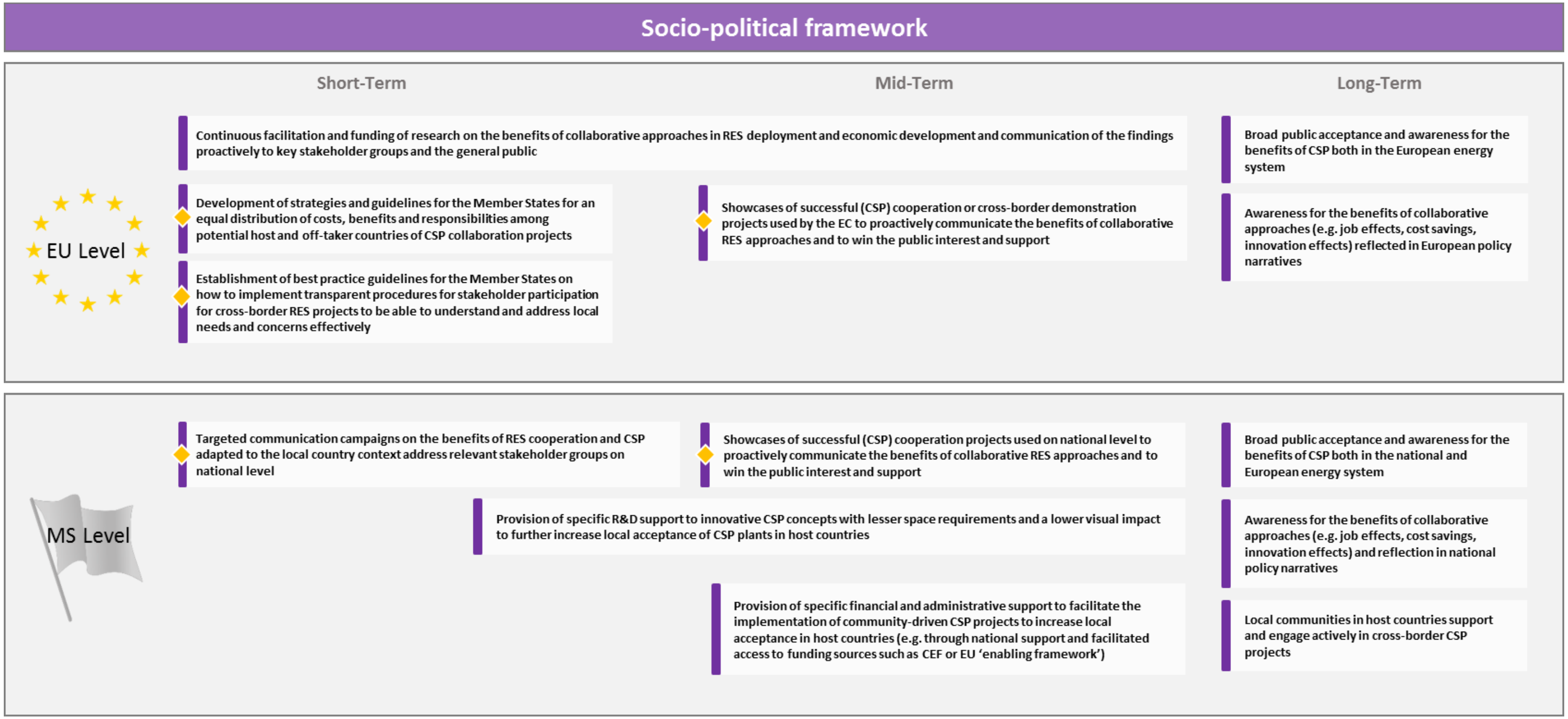


Figure 6: Steps to improve public acceptance and create a political narrative for collaborative CSP deployment in Europe (key milestones marked with diamond)

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6 Annex

Results of the online survey on the relevance of selected policy measures to support the implementation of CSP cooperation projects

Respondents were first asked to specify which type of stakeholder group they belonged to and which country(ies) they were mainly active in, in order to ensure that the answers covered a relevant target group. The result is shown in Figure 5. Geographically, the stakeholders specified that they were active in key countries in Europe (Germany, Spain, Portugal, Italy, Greece, Austria) and, globally, in the MENA region, Latin America, South Africa, Australia, Asia and the US.

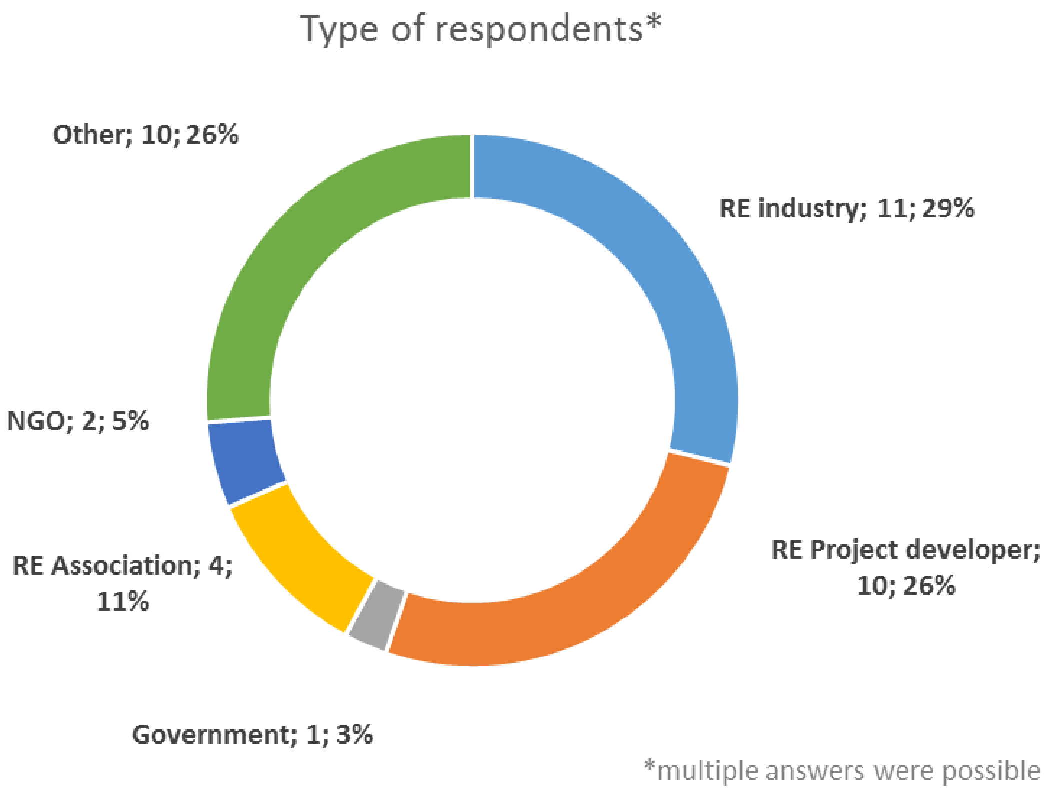

Figure 7: Characterization of the online survey respondents (n=33)

In the next step, the participants were asked to rate a selection of policy measures according to their relevance regarding the support of collaborative CSP projects. The following answers were possible:

- Very important → Crucial measure, to be addressed immediately and with high priority
- Moderately important → Lower priority or to be addressed in the longer term
- Not important → No crucial measure

§ The results for the three policy blocks (political and regulatory framework, techno-economic framework and socio-political framework) are shown in Figure 6, Figure 7 and Figure 8.

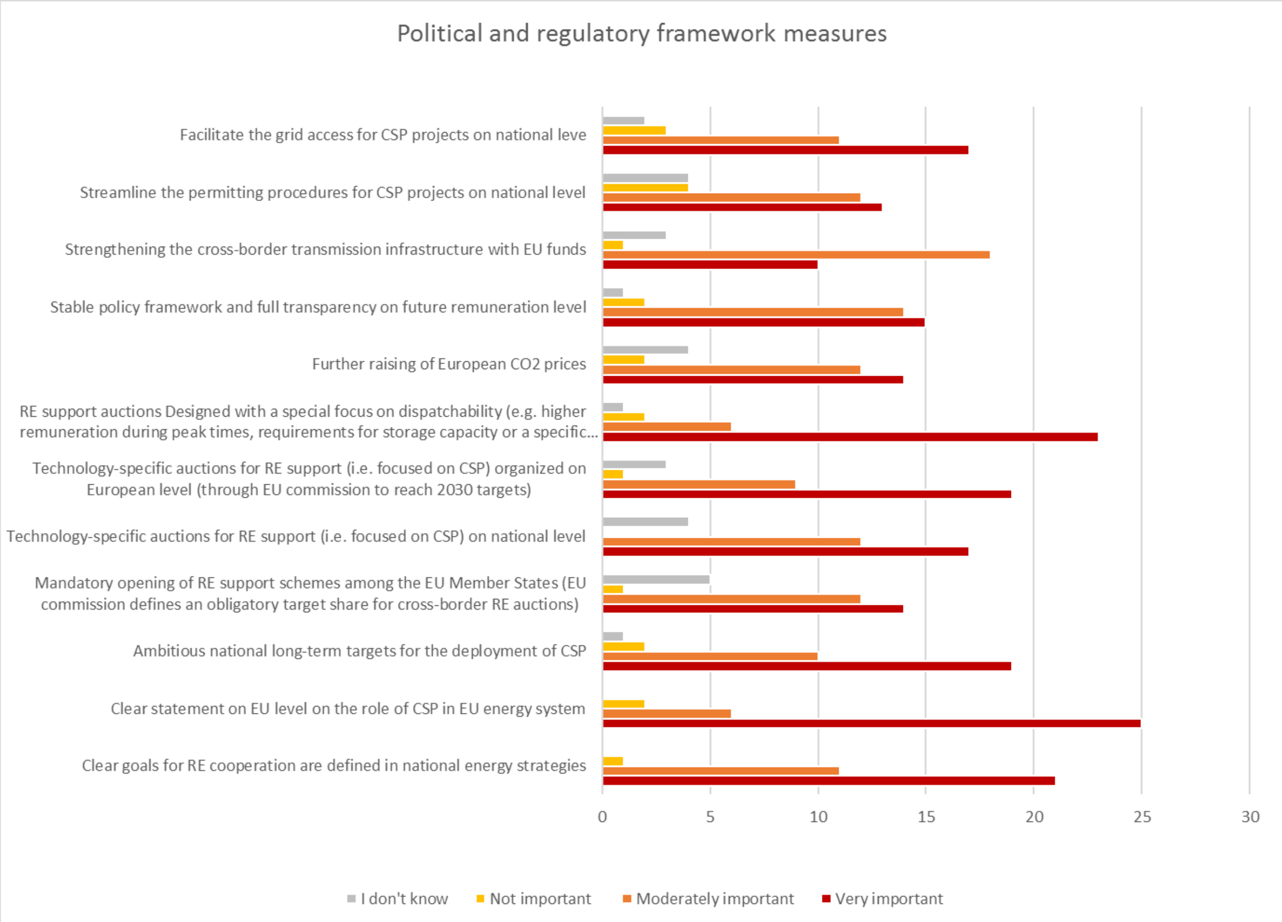

Figure 8: Online survey results: Rating of the relevance of measures to enhance the political and regulatory framework for CSP cooperation projects

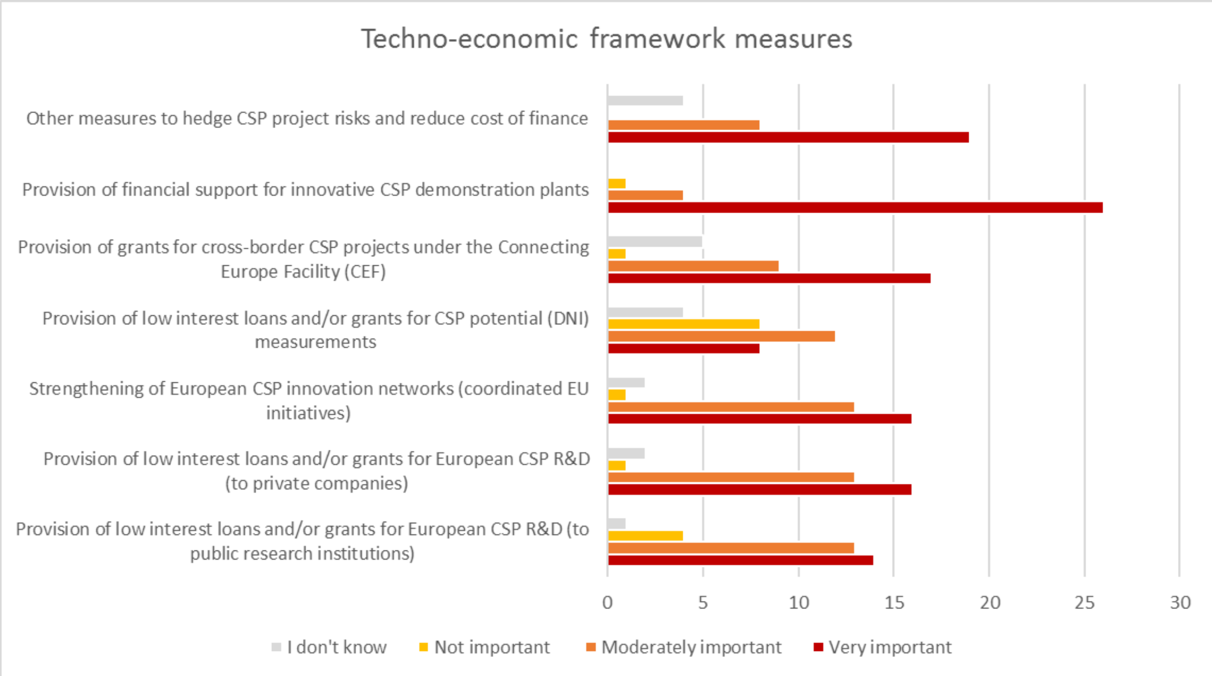

Figure 9: Online survey results: Rating of the relevance of measures to enhance the techno-economic framework for CSP cooperation projects

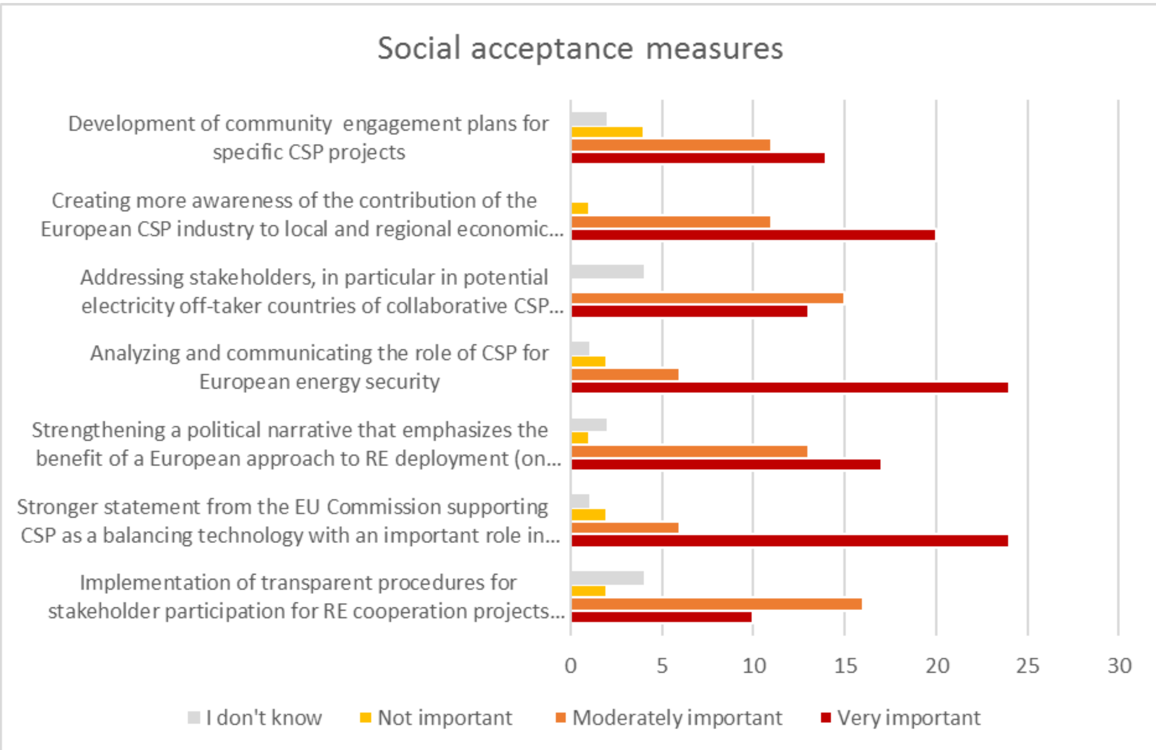

Figure 10: Online survey results: Rating of the relevance of measures to enhance social acceptance for CSP cooperation projects

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.

Name	Country	Logo
Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas – **CIEMAT**	ES	
University of Piraeus Research Center – **UPRC**	GR	
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Technische Universität Wien **- TU WIEN**	AT	
European Solar Thermal Electricity Association – **ESTELA**	BE	
COBRA Instalaciones y Servicios S.A – **COBRA**	ES	
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