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Obstacles for the CSP Cooperation Mechanisms

Lessons learned from the past

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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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Caldés N., Rodriguez I., Lechon Y., del Río P. (2018). *Analysis of the barriers to the use of the cooperation mechanisms for renewable energy in the EU.* Deliverable 4.1, MUSTEC project, CIEMAT, Madrid.

Lilliestam, J. (2018). *Whither CSP? Taking stock of a decade of concentrated solar power expansion and development.* Deliverable 4.2, MUSTEC project, ETH Zurich, Zurich.

Del Río, P. and Kiefer, C.P. (2018). *Analysis of the Drivers and Barriers to the Market Uptake of CSP in the EU.* Deliverable 4.3, MUSTEC project, IPP-CSIC, Madrid, Spain.

Del Río, P., Caldés, N. and Kiefer, C.P. (2018). *Potential Obstacles to the Use of Cooperation Mechanisms for CSP in the Future.* Deliverable 4.4, MUSTEC project, IPP-CSIC and CIEMAT, Madrid, Spain.

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1 INTRODUCTION

1.1 Background and motivation

MUSTEC focuses on assessing the opportunities that renewable energy cooperation may bring to the future market uptake of CSP in Europe. To achieve this goal, one of the first tasks consists in looking back to identify and better understand those factors that have influenced renewable energy cooperation in the past and, as such, may also influence the market uptake opportunities that renewable energy cooperation may bring for CSP in Europe.

According to many voices, renewable energy cooperation is expected to play a corner stone role as a way to ensure an effective and affordable energy transition in the EU, taking advantage of trade within the internal market, safeguarding security of energy supply, coordinating climate adaptation measures and optimising the cost-effectiveness of actions.

In this context, Europe wants to promote a cooperative RES deployment where the resources are most abundant, where the overall system costs would be minimized (e.g.: reduced need for backup, avoided grid investments, etc) or where overall social benefits would be maximised (e.g.: increased security of supply, GHG savings, avoided local air pollution, employment effects, innovation effects, etc) (DG-ENER, 2018).

In order to provide Member States (MS) with more flexibility and achieve the EU RES target in a more cost-effective way, the Renewable Energy Directive (RED) sets the legal framework for the use of cooperation mechanisms. While the Directive specified the general accounting rules of these mechanisms, their design and implementation were left to the cooperating MS. As described in articles 6, 7, 8, 9 and 11 of the Directive 28/2009/EC, MS could, depending on their needs and priorities, choose from the four possible cooperation mechanisms (Caldés et al. 2018, 2019).

However, despite several expected benefits of those mechanisms, barriers of heterogeneous nature have prevented their wide use among MS, as demonstrated by their limited use since 2009 (see Caldés et al. 2018 for further details).

One of the renewable energy technologies which may benefit from the use of the cooperation mechanisms is Concentrated Solar Power (CSP). Compared to intermittent Renewable Energy Technologies (RETs), CSP has a main distinguishing feature: it can be equipped with low-cost thermal energy storage, which allows it to provide dispatchable renewable power. Generation can thus be shifted to times when the sun is not shining or to maximizing generation at peak demand times. It can then be a cost-effective, flexible option in different places, especially with increasing shares of variable renewable electricity. However, there are several drivers and barriers to the deployment of this technology, which have been extensively analyzed within the project's framework.

Therefore, considering this background, a relevant research question is, then: what are the most relevant drivers and barriers to the use of the cooperation mechanisms specifically for CSP?

1.2 Objective and structure of the report

The aim of this report is to provide an overview of the MUSTEC findings regarding the lessons learnt and key factors affecting CSP, the cooperation mechanisms, and consequently the obstacles encountered by the cooperation mechanisms for CSP. To this end, the following activities have been conducted:

- First task was to answer two research questions: (i) What have been the main drivers and barriers to the use of the cooperation mechanisms in the past? and (ii) What are the expectations as to the main drivers and barriers to the use of the cooperation mechanisms beyond 2020? Therefore, it empirically assessed those drivers and barriers, providing a ranking of their importance and deriving policy recommendations which may activate those drivers or mitigate those barriers.
- Second task was to provide an integrated analytical framework to identify the drivers and barriers to CSP deployment, empirically identify those drivers and barriers to CSP deployment in the EU in the past and future with the help of a literature review and rank those drivers and barriers according to the views of investors and other relevant stakeholders involved in CSP.
- As a result of the literature reviews carried out from the above activities, two lists of potentially relevant factors were obtained. One of these lists included factors which were acting or could potentially act as drivers and barriers to the use of cooperation mechanisms for RETs, whereas the other list included drivers and barriers to CSP deployment in the EU in the past and the future. An analysis of each factor was carried out in order to assess if they were relevant as drivers and barriers to the use of cooperation mechanisms for CSP in the future. These led to a reduced list of 20 factors, 15 of them originating from the first task, while the other 5 from the second one.

  Whereas the previous analyses focused on the past and the future, the lack of use of these mechanisms specifically for CSP made it less interesting to ask about the past. Therefore, the focus was on the future drivers and barriers to the use of the cooperation mechanisms specifically for CSP, which is also in line with the overall goal of the MUSTEC project.

  Accordingly, a survey was launched asking directly different types of stakeholders in different types of countries (a potential host and a potential off-taker) to fill a short on-line questionnaire.

An overall description of the approach adopted for answering the abovementioned research questions, is presented in Figure 1.

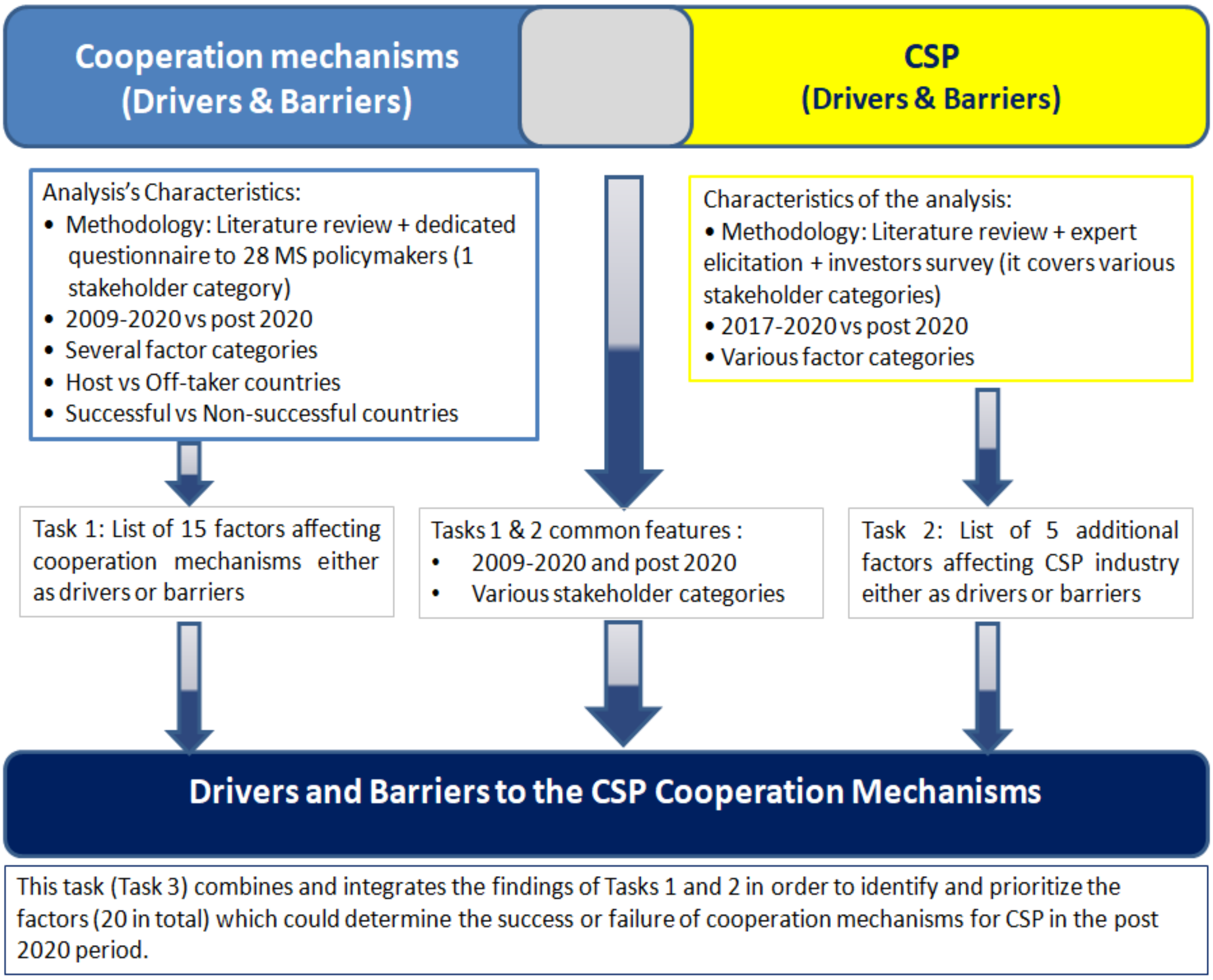

Figure 1: Illustrating the analytical framework

2 GLOBAL CSP EXPANSION

2.1 Market development and capacity growth

Concentrating solar power has a lively history with ups and downs, but currently there appears to be more up, in terms of costs and expansion and, in part, in terms of industry development. In May 2018, 84 CSP stations larger than 10 MW were operational in 11 countries, with another 23 projects (including 3 hybrids) under construction in 7 countries. The global operational CSP capacity was 5.2 GW, up from 490 MW 10 years earlier, with an expected generation of 14.3 TWh/a, and with another 1.7 GW (until May 2018) under construction. The current CSP fleet is less than 1/4 of the 23.6 GW expected in past projections, and the expansion pace remains less than 1/4 of that expected, but the technology continues to grow, albeit slowly.

The CSP expansion happened in four distinct phases, each characterized by a geographical scope, a particular policy setting, and with distinct changes in the industry structure. In the first phase, the 9 SEGS stations were built in the Californian desert under PURPA, a Purchase Power Agreement (PPA) scheme based on avoided costs of additional fossil fuel generation. As the natural gas price fell in the late 1980s, the PURPA tariffs fell too, and in the aftermath of this, the responsible company failed to finance further projects under construction and went bankrupt in 1992.

The second phase was triggered as the Spanish government instated a feed-in tariff (FIT) for CSP in 2007. This policy led to a period of rapid CSP expansion in Spain (2007-2013), leading to 2.3 GW installed capacity over 7 years. As the Spanish feed-in tariff was limited to ≤50 MW stations, operators often split larger stations into 50 MW independent units, inflating the number of Spanish stations (49 of the currently operational 84 stations worldwide are Spanish) (del Rio et al., 2018a; Lilliestam et al., 2014; Martin et al., 2015; Xu et al., 2016). The Spanish phase came to an end as the government cancelled the FIT scheme in late 2012 and expansion stopped.

The third phase, 2013-2016, saw a shift in expansion away from Spain to a range of different countries, including a shift back to the US but also to emerging countries such as South Africa, Morocco and India. This phase is characterised by a change in policy setting from an administratively defined FITs to competitive PPAs, which were the instrument of choice in all countries expanding CSP from 2013-2016.

This phase saw rapid growth in capacity – almost 2 GW added outside Spain in 4 years – driven by policy support in the US, where 1.2 GW were built. As the continuation of the US support was uncertain, the expansion in the US stopped, leaving a handful of smaller markets the only home of CSP (Lilliestam et al., 2018; Lilliestam et al., 2017).

In September 2016, the Chinese government announced a new support policy scheme for 20 projects of 1.35 GW (CSP Plaza, 2016) in total, marking the beginning of the fourth phase of global CSP expansion. This policy, to which the Chinese government explicitly refers as an R&D, instated a FIT which was higher than PPAs achieved in the US and South Africa, and thus slowed the downwards trend in CSP remuneration. At the same time, projects awarded PPAs in South Africa and Morocco started to come online, and with the completion of auctions and the signature of new PPAs, the pipeline of projects under construction grew again.

This phase is marked by more optimism about the future of CSP and for the first time in a long time, saw the entry of numerous new actors gathering experience with the projects in their domestic market but also participating in projects abroad. Nevertheless, also in this most recent phase, the expansion pace is only 1/4 of that expected in scenarios of the last 10 years.

An overview of the CSP capacity in operation, as well as under construction is presented in Figure 2.

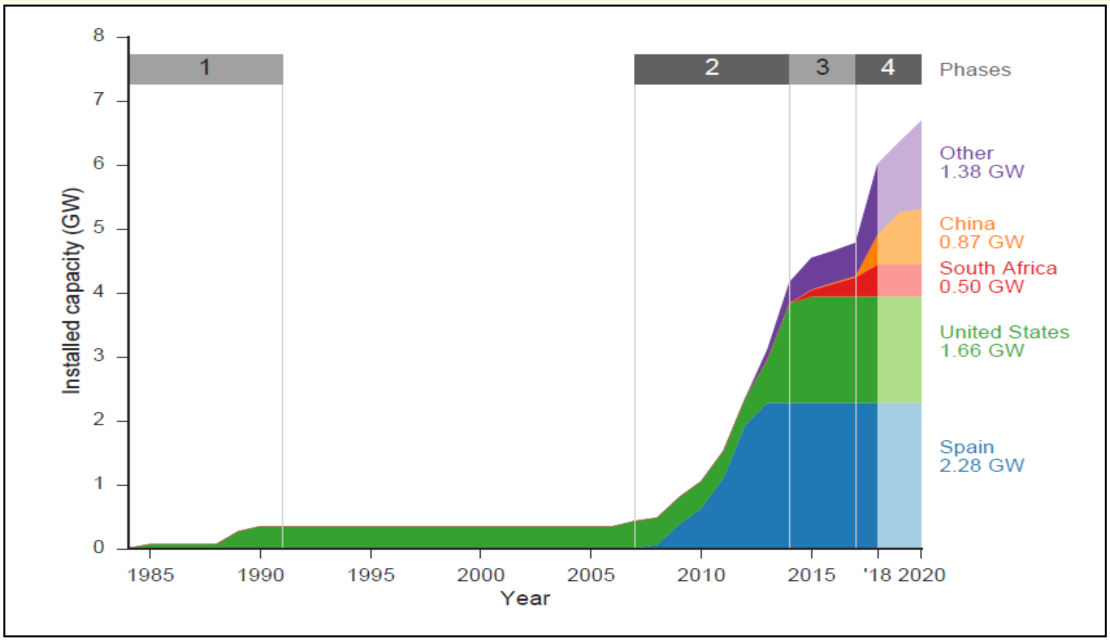

Figure 2: Global CSP capacity operational (1984-2018), and CSP stations under construction (2018-2020).

Source: Lilliestam, 2018

2.2 Technology choices

Three different types of CSP technologies are ready for commercial deployment: parabolic trough, power tower and Fresnel (technologies described in order of decreasing technological maturity). These have largely the same properties in terms of storage possibilities and power blocks and differ mainly in the temperature of the collected solar energy and the way they collect it: through long parabolic mirrors (trough) or several flexible flat mirrors on a single axis (Fresnel), or through a large number of individual flat mirrors aimed at a central receiver (tower) (IEA, 2010).

Past studies agree that the trough technology is the most mature, but towers are often seen as likely to catch up and perhaps surpass troughs as the dominant technology, because of their higher temperatures and lower parasitic, especially for high solar multiples and large storages, leading to higher efficiency (Trieb et al., 2015). Fresnel is interesting especially because its long flat mirrors are simpler, and potentially cheaper, to manufacture and operate than parabolic trough mirrors or the myriad of heliostats of tower stations (IRENA, 2012). In addition to an anticipated shift away from troughs, a development to larger units is expected, to trigger economies of scale and reduce costs O&M (IEA, 2010).

By far most CSP stations are parabolic trough: 67 of the 78 existing stations (excluding hybrids) are troughs, as are 11 of the 20 under construction. Hence, troughs have been and remain the dominant technology choice across the world, especially in Spain, where almost all stations (2/3) are troughs. There is a trend towards towers, considering these hardly existed 5 years ago, but so far, the expectation that towers would take over as the dominant technology has not been met. The following figure, Figure 3, demonstrates the new added CSP capacity per technology type on an annual basis.

Furthermore, there is a clear trend towards larger storage and higher load factors.

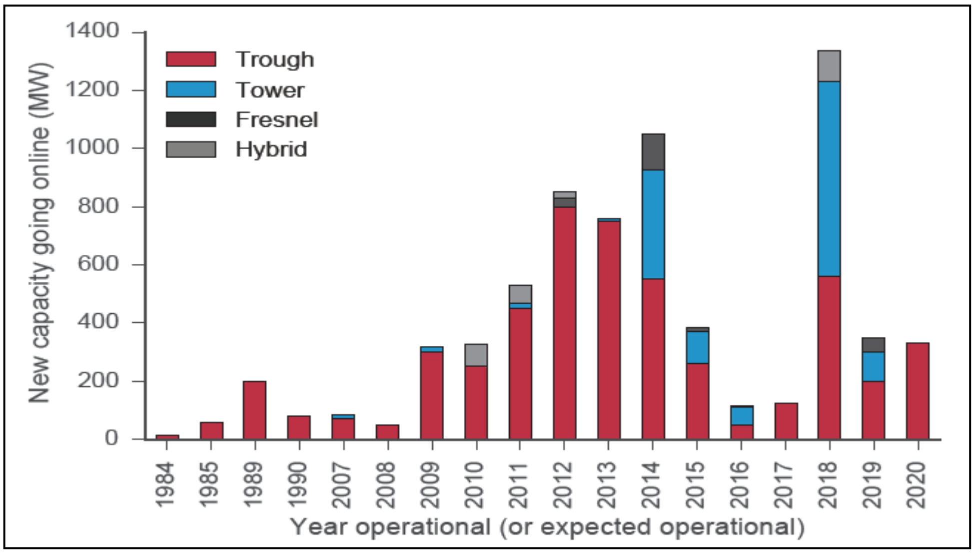

Figure 3: New CSP capacity added each year, 1984-2018 (operational) and 2018-2020 (under construction), including hybrids.

Source: Lilliestam, 2018

Whereas CSP stations without storage were the by far most common configuration pre-2015, currently there are only two stations without storage under construction.

2.3 LCOE TRENDS

The cost trend for LCOE is presented in Figure 4. The LCOE decreased during the first CSP expansion phase, from USD 0.66 per kWh in 1984 to about USD 0.2 per kWh in 2007. Following the shift to Spain, costs increased to USD 0.28 per kWh in 2008/2009 and decreased steadily to USD 0.17 per kWh in 2014. After this, a shift to new countries and less mature technologies (especially towers) led to increasing costs in 2015/16 (USD 0.22 per kWh). This is very far from the typical costs for a new CSP station stated by SunShot (USD 0.12 per kWh; (Mehos et al., 2016), and only some 20% lower than at the beginning of the Spanish phase in 2008. In the current, fourth phase, the cost decrease continues and has picked up speed compared to before: stations under construction and bound for completion 2018-2020 cost on average USD 0.12 per kWh, 45% lower than 2015/16.

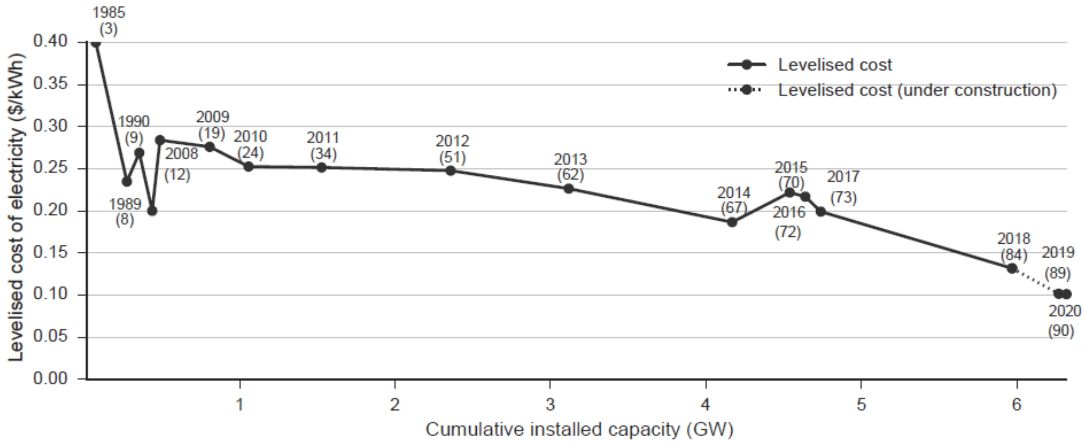

Figure 4: Cost development (LCOE) of 75 of the 78 existing CSP stations and 15 of the 20 stations under construction (excl. hybrids). The numbers in brackets are the cumulated number of stations which are operational or expected operational in each year.

Source: Lilliestam, 2018

The cost for ongoing CSP projects is on average USD 0.12 per kWh, and is below USD 0.10 per kWh in some regions, notably in China. If projects under construction materialize as they promise, they signify an LCOE decrease of almost 50% in 5 years – an unprecedented pace, which gives hope for the future of the CSP technology. This cost is still much higher than that of PV or wind power and it is higher than expected 5-10 years ago, but for the first time in a long time, the LCOE trend of CSP shows solidly and strongly downwards.

Recent bids and awarded PPA contracts suggest that the downward trend is robust and, most importantly, that costs well below USD 0.10 per kWh are realizable in countries other than China, including as disparate places as Chile, Dubai and Australia. The learning rates are high, exceeding 25% for the most common trough configurations in the recent years, which is higher than most past estimates; as the expansion pace has been much slower than previous projections, the LCOE is still higher than expected.

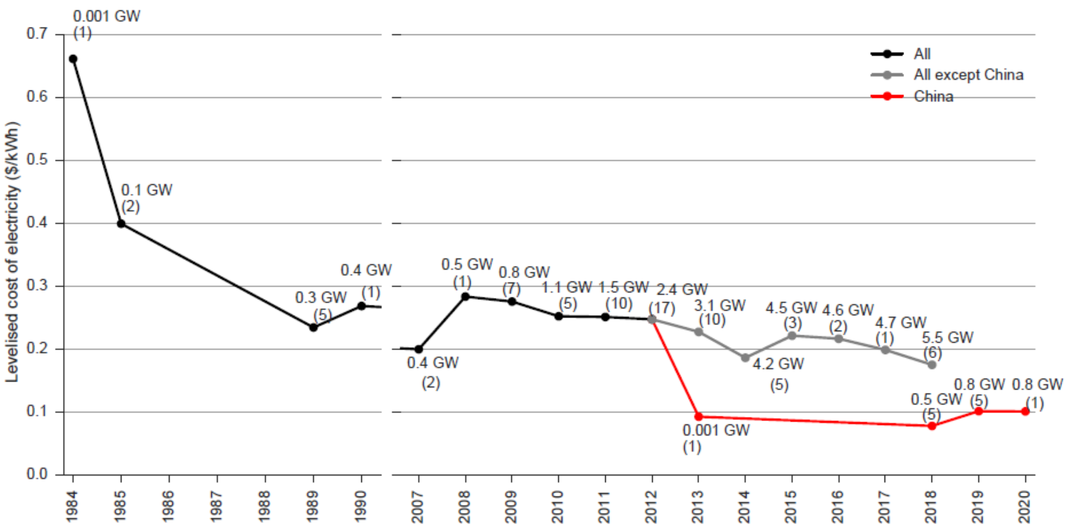

Figure 5: Cost development (LCOE) of 75 of the 78 existing CSP stations and 15 of the 20 stations under construction (excl. hybrids), split for Chinese and non-Chinese stations (1984-2020). The numbers in brackets are the cumulated number of stations which are operational or expected operational in each year.

Source: Lilliestam, 2018

There are two somewhat surprising trends, both underlining that technology costs are decreasing quickly, and one caveat. First, costs are decreasing fast for parabolic trough stations – but even faster for solar towers, so that they are, overall, already cheaper than troughs. This is surprising, as there are only few tower projects and it is a less mature technology than troughs. In part, this is because tower projects have larger storages than trough projects, and because a larger share of the towers are Chinese, where costs tend to be lower across all technologies, but it may also represent a shift in technology: towers have long been expected to surpass troughs in terms of both efficiency and cost, and perhaps this is what it is observed.

Second, the LCOE of stations with larger storage, and thus a higher degree of dispatchability, are lower: previous research has suggested that adding more storage to a CSP configuration *does not increase* its LCOE – but (Lilliestam, 2018) show that the LCOE rather *decreases* with storage size. This combined with the strong trend toward larger storage confirms past expectations and offering proof that it is the dispatchability – and not cost or potential – that offer the *raison d'être* for CSP.

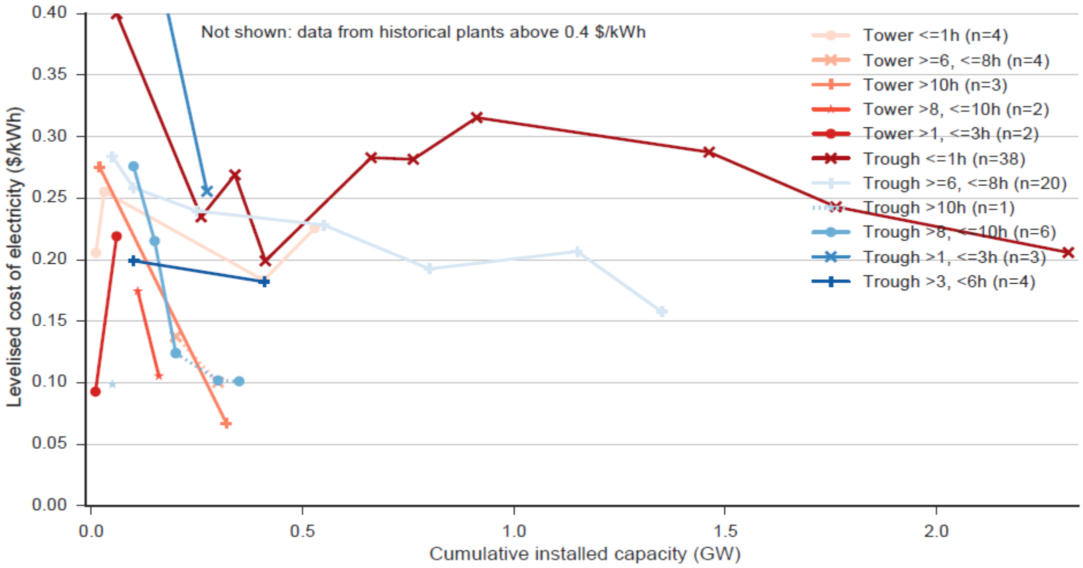

Figure 6: LCOE development of parabolic trough and tower stations (operational & under construction), by storage size (excl. hybrids).

Source: Lilliestam, 2018

In terms of expansion, the overall picture is also largely positive. More countries than ever before are building CSP, and although the expansion is much slower than that of PV or wind power, and although it is much slower than past projections prophesized – less than half the expected capacity in 2018, and about a quarter of the expansion pace – the CSP expansion trajectory appears more robust than ever: there are several hundred MWs under construction in 7 countries, and over one thousand MW under advanced development.

3 RENEWABLE ENERGY COOPERATION IN EUROPE

3.1 Cooperation mechanisms of the RES Directive 28/2009/EC and projects implemented

The **Renewables Energy Directive 2009/28/EC** defined an EU 20% RES target as well as National binding RES targets expressed as a percentage of RES gross energy consumption. Such targets were set based on “flat rate approach” that only considered MS gross domestic product and their historical RES deployment. As a result, national targets were not necessarily correlated with MS RES potentials nor with their RES generation costs and some MS with scarce RES resources or high generation costs found it challenging to meet their targets domestically while for others –with abundant resources and/or cheaper generation costs- it was easy to meet their target and even go beyond such target. In order to provide MS with more flexibility and achieve the EU target in a more cost-effective way, the RED Directive 2009/28/EC set the legal framework for the use of cooperation mechanisms. While the Directive specified the general accounting rules of these mechanisms, it is important to note that their design and implementation is left to the cooperating MS. (Caldés and Díaz-Vazquez, 2018).

Table 1: Cooperation mechanisms of the RES Directive (2009/28/EC)

Article 6: Statistical transfers	**In this case, renewable energy (electricity, heat or transport energy) which has been produced in one MS is virtually transferred to the RES statistics of another MS, counting towards the national RES target of that MS.**
Article 7: Joint Projects between EU MS	Allows EU MS to finance a RES project jointly thus sharing the costs and benefits of the project and developed under framework conditions jointly set by two or more MS. The involved MS define which share of the energy production counts towards which MS target.
Article 9: Joint Projects with third countries	Joint projects can also be implemented between MS and third countries (i.e.: countries outside the EU). A precondition is that an amount of electricity that equals the electricity amount generated from RES and subject to this joint project is physically imported in the EU.
Article 11: Joint Support Schemes	Under this scheme, MS merge or coordinate (parts of) their RES support schemes and jointly define how the renewable energy produced is allocated to their national targets.

Source: BETTER project

Since 2009, the cooperation mechanisms have not delivered as expected and, as of today, only four cooperation mechanisms have successfully been implemented in Europe, in line with Table 2.

Table 2: Projects developed under the cooperation mechanisms

Cooperating Countries	Coop. Mechs.	Type of agreement	Year
Sweden/Norway	Art. 11	Joint Certificate Scheme	January 2012
Germany/Denmark	Art. 11	Mutually-opened auctions	July 2016
Luxemburg/Lithuania	Art. 6	Statistical Transfer	October 2017
Luxemburg/Estonia	Art. 6	Statistical Transfer	November 2017

3.2 Identification of drivers and barriers for cooperation mechanisms

3.2.1 What have we learned from the past?

Some of the most commonly reported reasons to cooperate include: (i) lowering the costs of reaching the national 2020 RES targets, (ii) closing the potential gap between RES production and RES target and/or interim target, (iii) cooperation for technology development and (iv) long term cooperation and electricity imports/exports.

The limited use of the cooperation mechanisms since 2009 demonstrates that beyond cost-savings and compliance with State aid decisions, there exist other direct and indirect drivers and hurdles that must be considered when considering a cooperation agreement. Examples of those include, among others, grid-related bottlenecks, avoided local and global air pollution, security of supply, employment effects, innovation effects, etc. (Caldés and Díaz-Vazquez, 2018). Furthermore, the priorities and constraints of each MS as well as the particularities of each cooperation case may also determine the feasibility as well as interest towards a particular cooperation mechanism and its design choice.

3.2.2 Characterization of the identified factors

Based on the literature review and expert consultation, a list of potential factors positively or negatively influencing MS decision to use of the cooperation mechanisms has been identified for the period (2009-2017). Similarly, using the proposed analytical framework, the identified factors have been characterized according to a set of criteria.

STEP 1 has resulted in a list of more than forty factors (which can play either a barrier or a driver role depending, among others, on the role the country is playing as well as the context). These forty factors have been classified according to seven categories: (i) political factors, (ii) technical factors, (iii) legal factors, (iv) geopolitical factors, (v), public acceptance and (vi) economic factors and (vii) environmental factors.

Table 3: Classification of potential influencing factors based on different categories and their possible role for different country types.

	Country role		
POLITICAL	**Off-taker**	**Host**	**transit**
Political support at the National level			
Uncertainty about the design options to implement coop. Mechs			
Difficulties in communicating benefits			
Uncertainty about the post 2020 regulatory framework			
Unambitious post 2020 RES targets			
Political support at the regional level			
TECHNICAL	**Off-taker**	**Host**	**transit**
Import/supply dispatchable/flexible RES (to improve system management)			
Foster technology research and knowledge transfer			
Contribute to improve tech. performance and cost reductions			
EU guidance in implementing the cooperation mechanisms			
Lack of market and grid integration			
Challenges in quantifying indirect associated costs and benefits			
Limited interconnection capacity between some MS			
LEGAL	**Off-taker**	**Host**	**transit**
Uncertainty on state-aid compliance			
Heterogeneous regulated energy prices and support schemes across MS			
Obligation to open support schemes			
Lack of sanctions for non-compliance with 2020 RES targets			
GEOPOLITICAL FACTORS	**Off-taker**	**Host**	**transit**
Foster political and economic relations with other MS			
Domestic industrial interests			
Improve security of supply (diversification of RES sources)			
Jointly test new support schemes			
Move towards creation of an internal energy market			
Potential resistance from transit countries			
Resistance to loose sovereignty and control over energy market			
"First mover risk"			
PUBLIC ACCEPTANCE FACTORS	**Off-taker**	**Host**	**transit**
Public reaction in off-taker country (investing taxpayers money abroad)			
Public reaction in host country (NIMBY)			
Public reaction in transit country (visual impact of electricity grid)			
Public perception of environmental benefits			
Public perception of socio-economic benefits (jobs, econ activity, etc)			
Public perception of Energy Security issues			

Public perception of pro-European values (cooperation, integration, etc)			
ECONOMIC FACTORS	**Off-taker**	**Host**	**transit**
Cost savings in MS target achievement			
Generate revenues from domestic resources			
Attract foreing investments to deploy domestic plants			
New domestic jobs and industrial opportunties			
Cost savings at the EU level			
Oligopolies (lack of realized competition)			
ENVIRONMENTAL FACTORS	**Off-taker**	**Host**	**transit**
Contribute to the long term decarbonization of the energy mix			
Alignment with Paris Agreement objectives			
Climate leadership			
Access to finance under the EU sustainable Finance Action Plan			
Public concern for climate change as a foreign policy priority			

Source: Caldés et al., 2018

After this preliminary assessment of the potential factors influencing MS decision making process, the next section presents the results from a survey questionnaire aimed at assessing the degree of relevance – either as a barrier or driver- of the identified factors.

3.2.3 Answers from MS members

The survey questionnaire was answered by eighteen MS who were asked to answer the question: "How has each factor influenced the use of the cooperation mechanisms in your country?" Next, for each factor displayed in table 5, MS could choose from: -3 (very important barrier), -2 (important barrier), -1 (somehow important barrier), 0 (not relevant), 1 (somehow important barrier), 2 (important barriers) and 3 (very important barrier).

Figure 6 shows what has been the average score by category. From this figure various conclusions can be derived. First, results show that, in line with the expectations, there have been more barriers than drivers influencing the use of the cooperation mechanisms (shown by the higher number of factor categories to the left than to the right of the axis but also by the higher negative values). This result could partially explain the limited uptake of the cooperation mechanisms.

Among the categories that negatively influence MS decision to cooperate, legal, political, public acceptance and geopolitical factors stand out (in that order). On the other side, the categories that appear to have positively influenced MS decision to cooperate include environmental and economic factors.

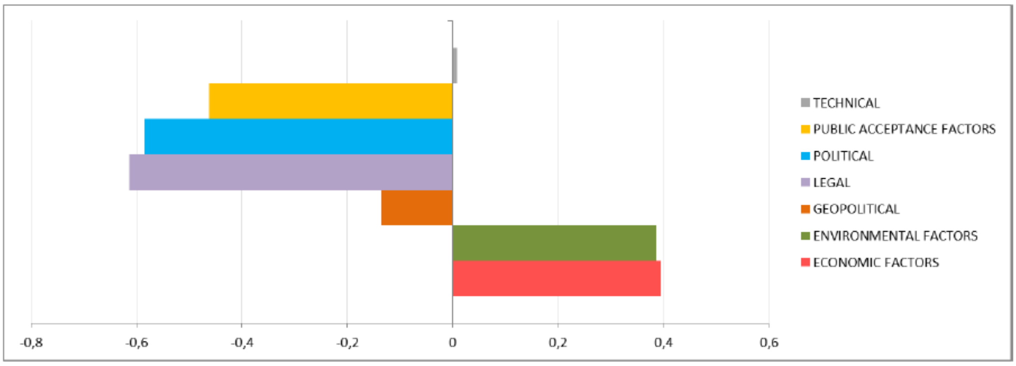

Figure 7: Average results of the survey questionnaire by factor category

Source: Caldés et al., 2018

Among the most relevant barriers to cooperation, the top five barriers include: (i) Public reaction in off-taker countries (investing taxpayers money abroad), (ii) Heterogeneous regulated energy prices and support schemes, (iii) Difficulties in communicating the benefits of cooperation, (iv) Resistance to loose sovereignty and control over national energy market and (v) Uncertainty about the design options to implement the cooperation mechanisms.

Among the most relevant drivers to cooperation, the top five enablers include: (i) Cost savings in MS target achievement, (ii) Contribution to improved technology performance and cost reductions, (iii) EU guidance in implementing the cooperation mechanism (iv) New domestic jobs and industrial opportunities & (v) Move towards the creation of an internal energy market.

As mentioned before, it is important to highlight that the average score obtained by the top five barriers is higher than the score of the top five drivers. This fact supports the idea that there have been not only more but more important barriers to cooperation than drivers in the past. This result is important for the decision-making process because it implies that if policy makers would like to activate the drivers or mitigate the barriers for the use of the cooperation mechanisms, they will have to implement different types of initiatives that go beyond energy policies.

Another finding from these results is that "political" and "public acceptance" factors are the most important categories which could partially explain the limited use of the cooperation mechanisms in the 2009-2017 period. On the contrary, "economic" and "environmental" factors categories are, on average, the stronger drivers for cooperation but in a lower absolute value than the barriers.

3.2.4 Answers by host vs. off taker countries

The next figure shows the different answers obtained by those countries that have renewable energy surplus (and thus could be potential host countries) versus those countries that are facing difficulties in meeting their 2020 RES target domestically (could potentially play an off-taker role in a cooperation agreement), based on Eurostat (2018).

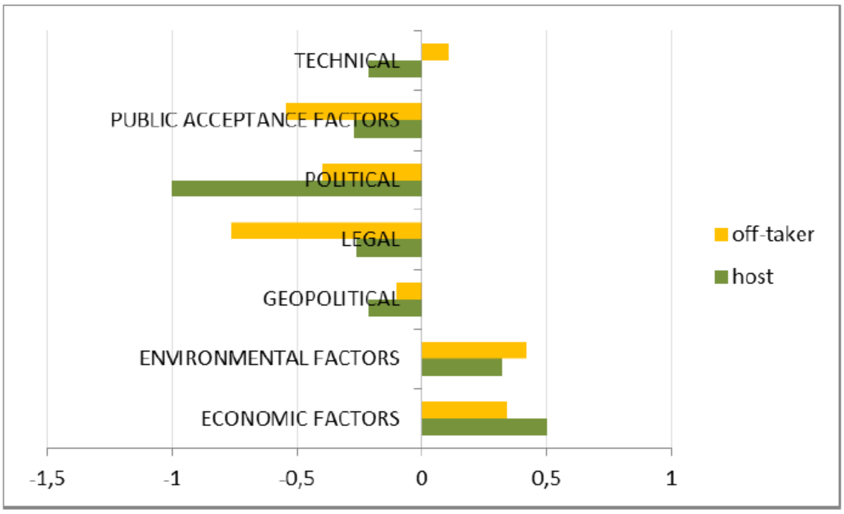

Figure 8: Factor categories analysis by host or off-taker countries

Source: Caldés et al., 2018

What can be concluded by the above figure is that most factor categories play the same role (either as barrier or as a driver) independently if the country is a host or off-taker country. However, the intensity of the effect is different. For the driver categories (economic and environmental factor categories), economic factors are more relevant for host countries while for the environmental factors, it plays a more important role for off-taker countries. As for the barriers, legal and public acceptance factors are more relevant for off-taker countries than they are for host countries.

On the other side, political and geopolitical barriers are more relevant for host countries than for host countries. The only category for which here is a significant (in direction and intensity) difference among host and off-taker countries is technical factors. For host countries, technical factors constitute a barrier while for off-takers, they constitute a driver.

3.2.5 Countries involved or not in the cooperation mechanisms

The results obtained from those countries that were involved in the cooperation mechanisms (YES) and those countries that were not (NO), interestingly, show significantly different patterns. As for technical aspects, those countries that were involved in cooperation indicated that, on average, technical factors played an enabler role while those that were not involved in any cooperation mechanism, stated that technical factors, on average, contributed to prevent their participation in cooperation mechanisms. Similarly, political factors played a positive role for those countries participating in cooperation agreements while negatively affected the decision to engage in cooperation agreements for those that did not participate. This result is not surprising and reinforces the fact that political support (at all levels) is fundamental both in positive and negative terms.

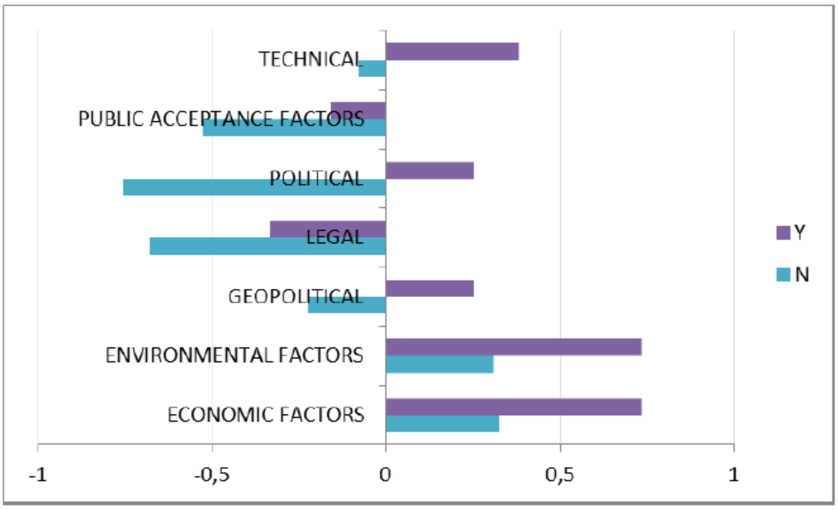

Figure 9: Factor categories analysis by participating/non-participating countries.

Source: Caldés et al., 2018

The same applies for geopolitical factors which show a different direction between countries involved in cooperation (that show a positive effect) and those that did not engage in cooperation (for which geopolitical factors negatively affect their decision to cooperate. As expected, for the other categories that have had a negative effect (public acceptance and legal factors), the intensity is lower for those countries that have participated in a cooperation mechanism. Also, as expected, for those categories that play an enabler role for both type of countries (environmental and economic categories), the intensity is larger for those countries actively involved in a cooperation mechanism.

One of the most outstanding results is that among those countries that participated in a cooperation, the more relevant enabling factors include: (i) Cost savings in MS RES target achievement, (ii) Contribution to improve technological performance and cost reduction, (iii) Obligation to open support schemes and (iv) Move towards the creation of an internal energy market.

On the other side, for the same countries, the factors that have played a more negative role include: (i) Public acceptance issues (off-taker public opposition towards using tax-payers money to finance projects abroad), (ii) Uncertainty on state aid compliance, (iii) Heterogeneous regulated energy prices and support schemes, (iv) First mover risk.

As for those countries that did not participate in any cooperation agreement, the most outstanding enabling factors include: (i) cost savings in MS target achievement, (ii) Contribute to improve technological performance and cost reductions, (iii) EU guidance in implementing the cooperation mechanism, (iv) Supply of flexible electricity, and (v) Foster technology research and knowledge transfer.

On the other side, the most important hurdles include: (i) Public acceptance (off-taker countries resistance to use tax-payers money to support a RES project abroad), (ii) Heterogeneous regulated energy prices and support schemes, (iii) difficulties in communicating benefits, (iv) resistance to loose sovereignty and control over the energy market, (v) Challenges in quantifying the indirect costs and benefits.

3.3 Drivers & Barriers to CSP industry

3.3.1 Results on the CSP drivers and barriers

Ten experts were asked about the relative importance of a wide array of drivers and barriers to CSP deployment in the past (until 2018) and the future (between 2018 and 2030). The questions are related to the TIS level (Del Río and Kiefer, 2018).

Several factors are clearly perceived to be more relevant to explain the deployment of CSP in Europe in the past. These are (in descending order of importance): deployment support, policy framework conditions and policy ambition and the fact that the technology is regarded as proven and, thus, technology risks are perceived as being low. Among the least relevant, three stand out (also in descending order of importance): carbon prices, complementarity with PV and the cooperation mechanisms of the RES Directive.

Regarding the perception on the relevance of the drivers of CSP deployment in the future, the three most relevant 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. The three least relevant include local manufacturing capabilities, a strong knowledge base and knowledge generation in the EU and the existence of a dominant design.

Therefore, framework conditions and ambition are considered a key driver both in the past and the future. It is interesting to note, however, that the perception of the importance of the drivers to deployment clearly differ between the past and the future. In particular the dispatchable feature of the technology is deemed highly relevant in the future, whereas its relevance is low in the past. This is related to the fact that CSP is regarded to provide a complementary generation profile to intermittent renewable energy sources which are also expected to make a significant contribution in the future. The fact that the relationship between CSP and PV is regarded as complementary in the future, but not in the past, is also in line with this interpretation. In contrast, deployment support is deemed very important as a driver in the past, whereas it is not expected to be so in the future. This is probably related to the lower maturity levels and high cost gap of CSP in the past, and with the expectation that the competitiveness of the technology in the future will be more related to its dispatchability property than to its costs in terms of LCOE, despite the high cost-gap being deemed a very important barrier in the past as well as in the future. The fact that cost reductions are not perceived as a main driver of the technology in the future is in line with this interpretation 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.

The experts agreed most on the role of Policy framework conditions and policy ambition, RD&D support, dispatchability, strong knowledge base and knowledge collaboration and existence of a dominant design (minimum standard deviation) and disagreed most on the role of regional policies (maximum standard deviation).

Regarding the perception of the importance of the barriers to CSP deployment in the past, three stand out: higher costs, retroactivity, lack of stability and ambition of targets and low levels of deployment support. Retroactivity, lack of stability and low deployment support is probably related to the policy conditions existing in the country where virtually all the CSP capacity had been installed in the EU (Spain) since 2010, with retroactive cuts and a renewable energy moratorium. The three least relevant are low competence in the CSP TIS, risk of environmental pollution and low international knowledge collaboration.

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 TIS, 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.

The experts agreed most on the role of retroactivity, lack of stability, ambition of targets, low international knowledge collaboration, low competence in the CSP TIS, risk of environmental pollution and project specific development necessary due to unavailability of standardized major components (minimum standard deviation), and disagreed most on the role of limited solar resource potentials, existence of a dominant design, general legal framework, overcapacity and meager electricity demand, competition with PV (maximum standard deviation).

3.3.2 Investors' survey

A specific survey to investors focused specifically on the DBs perceived by this type of stakeholders, taking into account the system-level DBs (at the TIS level) and, additionally and to some extent, the resources, capabilities and competencies (RCCs) of those investors. A distinction between the two CSP technologies (parabolic trough and solar tower) was made. Differently from the expert elicitation, which focuses on the DBs to all CSP technologies in the past (until 2018) and the future (up to 2030), the investor survey was focused on past DBs only (i.e., not on future ones) and on two CSP technologies (parabolic trough and solar tower). First, the main drivers for parabolic trough include both aspects of the technology (maturity, expected performance and dispatchability) as well as features of investors (previous technological experience, previous project realization experience and accumulated knowledge). It is quite logical that the maturity of the technology as well as knowledge and experience accumulation are key drivers of the technology, given that it is the most mature CSP design and the one which has attracted most investments in deployment. The fact that it is mature, proven and with a good performance record is obviously very attractive for investors. In addition, there is some path dependency regarding the influence of accumulated experience and knowledge in the firm when taking the decision to invest. This suggests the important role not only of external context conditions to the firm and the features of the technology, but also internal factors to the firm such as RCCs. On the other hand, the only relevant driver for investments in solar tower, according to investors, is dispatchability. This is also quite a logical result, given its lower maturity level when compared to parabolic trough and the much lower past investments (and, thus, accumulated experience) in this technology in the past.

Regarding barriers, an interesting and a priori unexpected result is the discouraging role played by administrative processes, construction permits and grid connection both for parabolic trough and solar tower. This certainly signals a role for policy intervention which mitigates those barriers.

As concerns the major differences between parabolic troughs and solar towers, technological maturity is a strong driver for parabolic troughs, while it is neutral for solar towers, dispatchability is a driver for both, yet a bit more pronounced for solar towers, the availability of standardized major components is a large driver for parabolic troughs, while it is a barrier for solar towers, previous experience accumulated by firms is a large driver for parabolic troughs as described above while it is much less so for solar towers. The aspects of energy and general policy (including framework and targets) are very similar drivers/barriers to both technologies. Internal financing and expected rates of return are also similar across the two configurations, as are administrative procedures and obtaining different kinds of permits etc.

3.4 Synthesis: an analytical framework on the drivers and barriers to the use of the cooperation mechanisms for CSP in the EU in the future

The following (15) factors from (Caldés et al. 2018) which are deemed relevant as drivers and barriers to the use of cooperation mechanisms for CSP deployment were selected:

- Existing interconnections capacities;
- Costs savings in MS target achievement;
- Contribution to improve tech performance and cost reduction in CSP;
- EU guidance in implementing the cooperation mechanisms;
- New domestic jobs and industrial opportunities;
- Move towards creation of internal energy market;
- Obligation to open support schemes;
- Alignment with the Paris objectives;
- Public reaction in importer countries (taxpayers money use);
- Heterogeneous regulated energy prices and support schemes;
- Difficulties in communicating benefits;
- Resistance to lose sovereignty over energy market;
- First mover risk;
- Public reaction in exporting country (Not In My Back Yard - NIMBY);
- Public reaction in transit country.

On the other hand, there are several drivers and barriers related to CSP deployment which could be relevant as drivers and barriers to the use of cooperation mechanisms for CSP deployment in the EU. In principle, this could be the case with all the factors identified in (Del Río and Kiefer, 2018). Thus, the criterion to select them was their relevance, as assessed in the above reference. As a result, the following (5) drivers and barriers were chosen:

- The dispatchability nature of CSP;
- Complementarily with PV;
- Policy ambition (renewable energy targets);
- Higher costs of CSP than other renewables (on LCOE basis);
- Low levels of deployment support in exporting country.

Whereas the other analyses focused on the past and the future, the lack of use of this mechanism specifically for CSP made it less interesting to ask about the past. Therefore, the focus of this task is on the future drivers and barriers to the use of the cooperation mechanisms specifically for CSP, which is also in line with the overall goal of the MUSTEC project.

Accordingly, a survey was launched asking directly different types of stakeholders in different types of countries (a potential host and a potential off-taker) to fill a short on-line questionnaire. The two countries chosen were Spain as a potential exporting country (host) and Germany as a potential importing country (off-taker). These countries were chosen for several reasons. Regarding the exporting country, this since currently, virtually all CSP capacity in Europe is deployed in Spain and that some researchers from MUSTEC are from institutions located in this country, which makes it easier to access key stakeholders. The choice of Germany is related to several reasons: 1) Germany being the main electricity consumer and, thus, one potential importer of electricity from other countries; 2) similarly to the case of Spain, some researchers are from institutions located in this country; 3) Germany has already been involved in a successful cooperation agreement with Denmark (where both countries opened support scheme to PV); 4) Germany has already implemented the obligation to partially open their support schemes; 5) Germany has remarkable interest (both from an industry as well as from a research point of view) in this technology; 6) the rapid and ambitious decarbonization pathway for Germany implies a sharp increase in variable renewables which may exacerbate the need to import dispatchable electricity (such as the one produced by CSP). The above-mentioned reasons seem to indicate that among other EU countries, Germany could potentially be interested in acting as an off-taker country for CSP cooperation projects in Spain.

Regarding key stakeholders to be interviewed, the initial idea was that, for the exporting country, CSP project managers, energy experts, public decision makers and grid operators would be interviewed. Key stakeholders in the importing country would include public decision makers, electricity distribution companies and grid operators.

The survey was launched in September/October 2018, as part of join efforts of WP3 and WP4 partners, and potential participants could fill the questionnaire until December 14th, 2018. The following table shows the questionnaire.

Table 4: Questionnaire

	How will each factor influence the use of joint projects for CSP in your country in the post 2020 time period? -3 (very important barrier)---0 (not relevant)---3 (very important driver)						
	-3	-2	-1	0	1	2	3
Existing interconnections capacitites							
Costs savings in MS target achievement							
Contribution to improve tech performance and cost reduction in CSP							
EU guidance in implementing the cooperation mechanisms							
New domestic jobs and industrial opportunities							
Move towards creation of internal energy market							
Obligation to open support schemes							
Alignment with the Paris objectives							
Public reaction in importer countries (taxpayers money use)							
Heterogeneous regulated energy prices and support schemes							
Difficulties in communicating benefits							
Resistance to lose sovereignty over energy market							
First mover risk							
Public reaction in exporting country (NIMBY)							
Public reaction in transit country							
The dispatchability nature of CSP							
Complementarity with PV							
Policy ambition (renewable energy targets)							
Higher costs of CSP than other renewables (on LCOE basis)							
Low levels of deployment support in exporting country.							

Source: del Rio et al., 2018b

3.5 Final Results

Interestingly, neither drivers nor barriers dominate the picture. Ten factors appear as drivers (Costs savings in MS target achievement, Contribution to improve tech performance and cost reduction in CSP, EU guidance in implementing the cooperation mechanisms, new domestic jobs and industrial opportunities, move towards creation of internal energy market, obligation to open support schemes, alignment with the Paris objectives, the dispatchability nature of CSP, complementarity with PV, policy ambition (renewable energy targets)) and another ten appear as barriers (public acceptance issues in importer countries - taxpayers money use, heterogeneous regulated energy prices and support schemes, difficulties in communicating benefits, resistance to lose sovereignty over energy market, first mover risk, public reaction in exporting country - NIMBY, public reaction in transit country, higher costs of CSP than other renewables on LCOE basis, low levels of deployment support in exporting country, existing interconnections capacities). Note that an average of the scores provided per factor has been calculated, without the respondent being forced to respond to a list of factors which was predefined as being either "driver" or "barrier". Therefore, whether the factors are either a driver or a barrier is contingent upon the (average) answers provided by the respondents. In fact, in some cases, a factor has been regarded as a driver by some respondents and as a barrier by others.

According to the responses to the questionnaire, the most relevant drivers to the use of the cooperation mechanisms for CSP in the future include the dispatchability nature of CSP, new domestic jobs and industrial opportunities, complementarity with PV and policy ambition (renewable energy targets) (in descending order of importance). The least relevant drivers are contribution to improve tech performance and cost reduction in CSP, costs savings in MS target achievement, obligation to open support schemes and move towards creation of internal energy market (also in descending order of importance). Therefore, a main feature of the technology (dispatchability) in the context of an increasing penetration of intermittent RES (PV or wind) is regarded as main influential positive factor in the use of the cooperation mechanisms for CSP. The relevance of the local development opportunities created by CSP deployment (probably only in the host country) is also considered as a main driver. Finally, policy framework conditions and, particularly, policy ambition regarding renewable energy targets is deemed a very relevant factor in this context. A result worth commenting is that cost savings, which was regarded as a relevant driver of the use of cooperation mechanisms in general is not considered as a very significant driver to the use of cooperation mechanisms specifically for CSP.

Regarding barriers, the higher costs of CSP compared to other renewables (on an LCOE basis), heterogeneous regulated energy prices and support schemes, resistance to lose sovereignty over energy market and existing interconnections capacities are regarded as the most relevant barriers (in descending order or importance). Public reaction in the different countries (transit, exporting (NIMBY) and importer countries (taxpayers money use)) are regarded as the least relevant barriers. Overall, these results stress the importance of market and policy fragmentation across the EU as main obstacles to the use of the cooperation mechanisms for CSP, together with one feature of the technology (comparatively high costs of CSP). These results suggest a case for an EU-level role in encouraging a greater coordination or harmonization of support schemes and enhanced interconnection capabilities. Also, among the most relevant factors that explain the drivers and barriers to the use of the cooperation mechanisms for CSP in the future we can find both drivers and barriers to CSP deployment and drivers and barriers to the cooperation mechanisms, both with a similar level of importance. However, it is interesting to note that the factors which acted as drivers of the CSP technology play a more important role as drivers to the use of cooperation mechanisms for CSP than the drivers to the use of the cooperation mechanisms in general. In contrast, the opposite is true regarding the barriers: the most relevant barriers to the use of the cooperation mechanisms for CSP are mostly relevant barriers to the use of the cooperation mechanisms in general, whereas (with the exception of "the higher costs of CSP compared to other renewables on an LCOE basis)" barriers to CSP deployment are relatively less important as barriers to the use of the cooperation mechanisms for CSP. Unfortunately, the results cannot be compared to previous contributions in the literature, since there is a lack of studies on the topic.

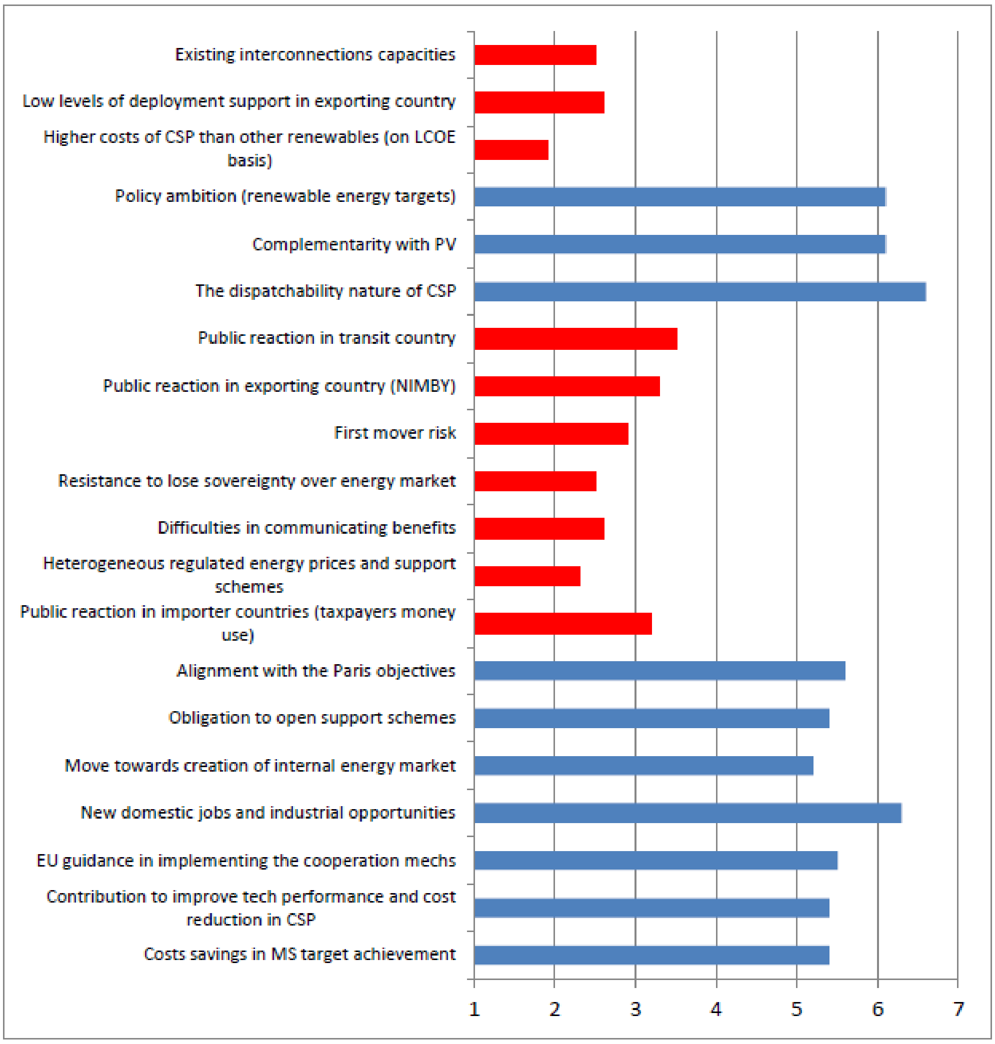

Figure 10: Most relevant drivers and barriers to the use of the cooperation mechanisms for CSP in the future.

Source: del Rio et al., 2018b

In addition, it is not possible to clearly distinguish between the views of host and off-taker countries since it has not been possible to identify the specific type of stakeholder completing the survey. However, it was tried to proxy it through the language used to answer the questionnaire, assuming that those answering the Spanish questionnaire are stakeholders in a potential host country (Spain) and those answering the German questionnaire are stakeholders in a potential off-taker country (Germany). However, for those answering the English questionnaire we could not make such assumption and, thus, those stakeholders remain "neutral" in the aforementioned sense. The following figure provides those results distinguishing between the Spanish respondents (16), German respondents (5) and English respondents (3). The comparative results show that large differences cannot be observed. This is confirmed by the t-tests that were carried out, which do not show statistically significant differences among the three groups. Stakeholders seem to have a very wide vision of drivers and barriers and exporting country stakeholders are probably conscious of the drivers and barriers in the importing countries and vice versa. All in all, it should be taken into account the low number of survey responses and the uneven distribution among the groups.

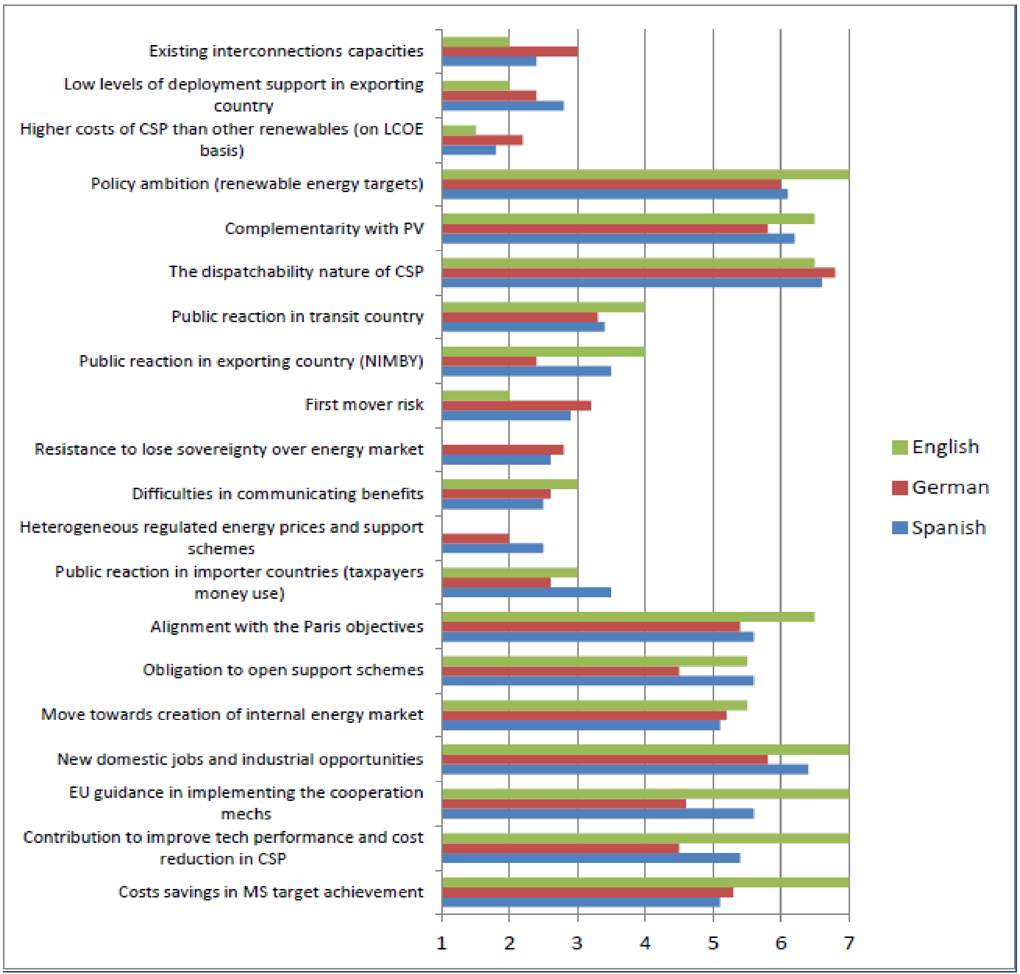

Figure 11: Most relevant drivers and barriers to the use of the cooperation mechanisms for CSP in the future (answers per language used to complete the survey).

Source: del Rio et al., 2018b

4 CONCLUSIONS

The aim of this report was to provide an overview of the MUSTEC findings regarding the lessons learnt and key factors affecting CSP, the cooperation mechanisms, and consequently the cooperation mechanisms for CSP, as a result of WP4 outputs.

When assessing the differences of drivers and barriers for the cooperation mechanisms, three different comparisons were adopted. At the first stage, the comparison was realised between those countries that have a RES surplus (potential host countries) and those countries that have a RES deficit (potential off-taker countries). The second comparison of DBs took place between countries that have actually engaged in a cooperation agreement versus those countries that have not, while a third comparison was conducted among the countries that did not participate in any cooperation agreement. It seems that in the first comparison (host and off-taker countries), most factor categories play the same role (either as barrier or as a driver) independently if the country is a host or off-taker country. However, the intensity of the effect is different.

When considering the countries that have entered in cooperation agreements versus the countries that haven't, the first two drivers in both cases are common, namely (i) Cost savings in MS RES target achievement, (ii) contribution to improve technological performance and cost reduction, with the rest of the drivers being differentiated. As concerns the barriers, the most important one in both categories is public acceptance resistance with utilizing the tax-payers money abroad.

Moving on to the assessment of the drivers and barriers for CSP deployment, the empirical analyses by (Del Rio and Kiefer, 2018) based on an expert elicitation and an investors' survey suggests that the degree of importance of each driver/barrier differs for different types of stakeholders (industry, researchers, policy makers and others), different time frames (past and future) and different CSP designs (parabolic trough and solar tower). Dispatchability is regarded as the main future driver of the technology, followed by policy framework conditions and policy ambition and complementarity with PV.

Although the findings from the previous two tasks suggests the relevance of several drivers and barriers, our empirical analysis (Del Rio et al., 2018b) based on a survey to different types of stakeholders suggests that neither drivers nor barriers dominate the picture when considering CSP cooperation mechanisms. Ten factors appear as drivers and another ten appear as barriers. According to the responses to our questionnaire, the most relevant drivers to the use of the cooperation mechanisms for CSP in the future include the dispatchability nature of CSP, new domestic jobs and industrial opportunities, complementarity with PV and policy ambition (renewable energy targets) (in descending order of importance).

Regarding the barriers, the higher costs of CSP compared to other renewables (on an LCOE basis), heterogeneous regulated energy prices and support schemes, resistance to lose sovereignty over energy market and existing interconnections capacities are regarded as the most relevant barriers (in descending order or importance). Public reaction in the different countries (transit, exporting - NIMBY and importer countries - taxpayers money use) are regarded as the least relevant barriers.

Our results suggest that, among the most relevant factors that explain the drivers and barriers to the use of the cooperation mechanisms for CSP in the future we can find both drivers and barriers to CSP deployment (i.e., those considered in Task 2) and drivers and barriers to the cooperation mechanisms (i.e., those considered in Task 1), both with a similar level of importance.

REFERENCES

BETTER project at: http://www.better-project.net

Caldés-Gómez, N., Díaz-Vázquez A.R. (2018). Promoting solar electricity exports from southern to central and northern European countries Extremadura case study., Publications Office of the European Union, Luxemburg. doi:10.2760/673989.

Caldés N., Rodriguez I., Lechon Y., del Río P. (2018). Analysis of the barriers to the use of the cooperation mechanisms for renewable energy in the EU. Deliverable 4.1, MUSTEC project, CIEMAT, Madrid.

Caldés N., del Río P., Gerbetti A., Lechon Y. (2019). Renewable energy cooperation in Europe: what next? Drivers and barriers to the use of cooperation mechanisms. Energies 12, 70.

CSP Plaza, 2016. China NDRC formally releases official notice on benchmark feed-in-tariff policy of CSP industry. 2 September 2016, CSP Plaza, Beijing, http://en.cspplaza.com/china-ndrcformally-releases-official-notice-on-benchmark-feed-in-tariff-policy-of-csp-industry.html.

Del Río P. and Kiefer C.P. (2018). Analysis of the Drivers and Barriers to the Market Uptake of CSP in the EU. Deliverable 4.3, MUSTEC project, IPP-CSIC, Madrid, Spain.

Del Río P., Penasco C., Mir-Artigues P. (2018a). An overview of drivers and barriers to concentrated solar power in the European Union. Renewable and Sustainable Energy Reviews 81, 1019-1029.

Del Río, P., Caldés, N. and Kiefer, C. P. (2018b): Potential Obstacles to the Use of Cooperation Mechanisms for CSP in the Future. Deliverable 4.4, MUSTEC project, IPP-CSIC and CIEMAT, Madrid, Spain.

Eleftheriadis, I.M., Anagnostopoulou, E.G., 2015. Identifying barriers in the diffusion of renewable energy sources. Energy Policy 80, 153–164.

European Commission DG-ENER, towards a more Europeanised approach to renewables policy– A possible instrument to support cross-border cooperation on renewables in the Multiannual Financial Framework post-2020. Background document for the Expert Consultation Meeting., Brussels, 2018.

European Commission (2009): Directive 2009/28/EC of the European Parliament and of the Council (l 140/16)

IEA, 2010. Technology roadmap. Concentrating solar power. International Energy Agency (IEA), Paris.

IRENA, IEA & REN21, 2018. Renewable Energy Policies in a Time of Transition, Available at: http://www.iea.org/publications/freepublications/publication/IRENA_IEA_REN21_Policies_2018.pdf.

IRENA, 2012. Concentrating solar power. International renewable energy agency (IRENA), Abu Dhabi.

Lilliestam J., Blumer Y., Geddes A., Labordena M., Späth L., van Vliet O. (2014). More than costs: on the fit between solar and renewable electricity policy motivations and energy system models, in: Bailey, S. (Ed.), Solar power: technologies, environmental impacts and future prospects. Nova, Hauppage, pp. 23-56.

Lilliestam J., Labordena M., Patt A., Pfenninger S. (2017). Empirically observed learning rates for concentrating solar power and their responses to regime change. Nature Energy 2, 17094. http://dx.doi.org/10.1038/nenergy.2017.94.

Lilliestam J. (2018): Whither CSP? Taking stock of a decade of concentrated solar power expansion and development. Deliverable 4.2, MUSTEC project, ETH Zurich, Zurich.

Lilliestam J., Barradic T., Caldés N., Gomez M., Hanger S., Kern J., Komendantova N., Mehos M., Hong W.M., Wang Z., Patt A. (2018). Policies to keep and expand the option of concentrating solar power for dispatchable renewable electricity. Energy Policy 116, 193-197. https://doi.org/10.1016/j.enpol.2018.02.014

Martin H. et al. (2015). Promotion of concentrating solar power (CSP) in Spain: performance analysis of the period 1998-2013. Renewable and Sustainable Energy Reviews 50, 1052-1068.

Mehos M. et al. (2016). On the path to SunShot: advancing Concentrating Solar Power technology, performance, and dispatchability. National Renewable Energy Laboratory (NREL), Golden.

SolarPACES, 2018. China to extend deadline for late CSP demos - but add penalty, SolarPACES, http://www.solarpaces.org/china-to-extend-deadline-for-late-csp-demos-but-addpenalty/.

Trieb F. et al. (2015). North Africa Case Study. German Aerospace Centre (DLR), Stuttgart.

Xu X. et al. (2016). Prospects and problems of concentrating solar power technologies for power generation in the desert regions. Renewable and Sustainable Energy Reviews 53, 1106-1131.