Dialogue on a RES policy framework for 2030

towards2030

Appropriate policy portfolios for still maturing renewable electricity technologies. The cases of concentrated solar power and wind offshore.

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About the project

The aim of **towards2030-*dialogue*** is to facilitate and guide the RES policy dialogue for the period towards 2030. This strategic initiative aims for an intense stakeholder dialogue that establishes a European vision of a joint future RES policy framework.

The dialogue process will be coupled with in-depth and continuous analysis of relevant topics that include RES in all energy sectors but with more detailed analyses for renewable electricity. The work will be based on results from the IEE project beyond 2020 (www.res-policy-beyond2020.eu), where policy pathways with different degrees of harmonisation have been analysed for the post 2020 period. **towards2030-*dialogue*** will directly build on these outcomes: complement, adapt and extend the assessment to the evolving policy process in Europe. The added value of **towards2030-*dialogue*** includes the analysis of alternative policy pathways for 2030, such as the (partial) opening of national support schemes, the clustering of regional support schemes as well as options to coordinate and align national schemes. Additionally, this project offers also an impact assessment of different target setting options for 2030, discussing advanced concepts for related effort sharing.

Who we are?

Vienna University of Technology, Energy Economics Group (EEG), Austria *(Project coordinator)*
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Energy Research Centre of the Netherlands (ECN), Netherlands
Center for European Policy Studies (CEPS), Belgium
National Technical University of Athens (NTUA), Greece
Consejo Superior de InvestigacionesCientificas (CSIC), Spain
Ecofys Netherlands and affiliates (Ecofys), Netherlands
REKK Energiapiaci Tanacsado Ltd (REKK ET), Hungary
European University Institute, Florence School of Regulation (EUI), Italy

Executive Summary

The main findings of this assessment can be summarised as follows:

This report aims to identify drivers and barriers for the deployment of renewable electricity technologies which are at an early deployment stage and have a significant potential to improve their quality and costs (still maturing technologies, or SMTs) and to propose policy portfolios which address these barriers. The focus is on two main SMTs expected to significantly contribute to the electricity mix in the medium term in the EU or elsewhere, such as concentrated solar power and wind offshore.

Drivers and barriers for RES (-E) technology deployment partly depend on the position of the respective technology in the technology diffusion curve. In addition, there are some technological particularities which affect the degree of diffusion of a specific technology which should be taken into account when proposing policy measures aimed at encouraging the deployment of the two SMTs considered in this report.

The literature suggests that significant technology improvements and cost reductions can be expected as both CSP and offshore wind industries scale up. However, CSP and offshore wind are at different maturity levels. Furthermore, there are also different maturity levels within e.g. the range of CSP technologies.

Cost reductions for both CSP and offshore wind are a result of several factors, including economies of scale, learning effects at both industrial and plant level, and increased plant/park size.

Offshore wind has experienced a larger cost reduction compared to CSP from 2000 until today, largely due to the fact that the annual and cumulative deployment rate has been significantly higher for offshore wind compared to that of CSP in the period. Trends towards larger turbines, larger wind farm sizes, integrated farm design, improved power forecasting and farm planning, active wake control, improved foundations, and coordinated planning will positively impact on the cost.

For CSP, cost reductions will be due to several factors, including economies of scale, learning effects at both the industrial and plant levels, increased size and technological improvements due to innovation. The first two are the result of deployment, whereas innovation is both the result of RD&D and, to a lesser extent, deployment. A large potential for innovation exists in CSP. In general, key technoeconomic drivers for the take-off of CSP are its high technological dynamism and competition between different designs, its potential for cost reductions, the possibility for hybridization, its higher value compared to other RETs and industry consolidation.

For both technologies, political drivers play a key role; these include targets (RES deployment and GHG emission reduction) in efforts to primarily combat climate change and energy security threats, and supporting policies, such as financial support (FiT, FiP and tradable green certificate schemes to promote RES). Key barriers to further CSP and offshore wind energy deployment include high costs relative to other (non-RES based) technologies generating electricity as well as cumbersome permitting procedures.

For CSP, specifically, key barriers include limited resource potentials in the EU (in particular in Northern EU), high costs, uncertain cost reductions, and retroactive cuts in remuneration, which has led to greater investor uncertainty.

For offshore wind, specifically, key barriers include high costs and grid connection challenges.

However, new challenges (barriers) also evolve as RES market share growth rates accumulate. For example, offshore wind players are experiencing increasing competition with other activities at sea, such as fisheries, shipping, dredging and sand extraction, for ideal locations for setting up offshore wind parks. Also, as RES penetration grows, wholesale electricity prices are reduced, which negatively affects the profitability of RETs (as well as other technologies) under market-based support schemes (notably, fixed FIPs).

In order to increase the deployment rate of both technologies, an obvious first policy recommendation is to provide as stable and credible support as possible. In turn, this entails setting long-term targets, ensuring predictable changes in the remuneration for new plants and avoiding retroactive changes for existing plants. Appropriate and well-designed remuneration schemes are necessary. Given the high capital costs of both technologies, FITs seem to be an appropriate instrument in this context. Furthermore, given the relevance of permitting procedures as a barrier for wind offshore developers, standardised, streamlined permitting procedures are therefore essential to enable large scale deployment in the 2020-2030 decade. Successful examples of one-stop-shops for permits have already been reported (for example such a one-stop-shop was set up by the UK government for its Round 2 offshore tendering process).

Outline

1 Introduction

The aim of this report is to identify drivers and barriers for the deployment of renewable electricity technologies which are at an early deployment stage and have a significant potential to improve their quality and costs (still maturing technologies, or SMTs) and to propose policy portfolios which address these barriers. The focus will be on two main SMTs expected to significantly contribute to the electricity mix in the medium term in the EU or elsewhere, such as concentrated solar power and wind offshore.

The three main hypotheses on which this analysis is based are:

1) The drivers and barriers to the adoption of a technology depend on the situation of the technology in the diffusion curve.

2) As a natural consequence of the previous point, appropriate instruments are different for different stages.

3) In addition, there are technology-specific barriers which have to be addressed by policy measures in order to encourage the uptake of these technologies.

The theoretical framework is based on an integrated framework which strongly builds on innovation studies but where several approaches were combined. These approaches are innovation studies (the technological innovation systems approach and the functions of innovation systems), the traditional environmental economics perspective, the learning effects literature and the literature on renewable energy deployment instruments. This framework has been described elsewhere in detail (del Río 2012, del Río and Bleda 2012, del Río and Peñasco 2014).

The starting point is that, as stressed in IEA (2011, p.99), the main challenges to deployment change as progress is made along this deployment curve.

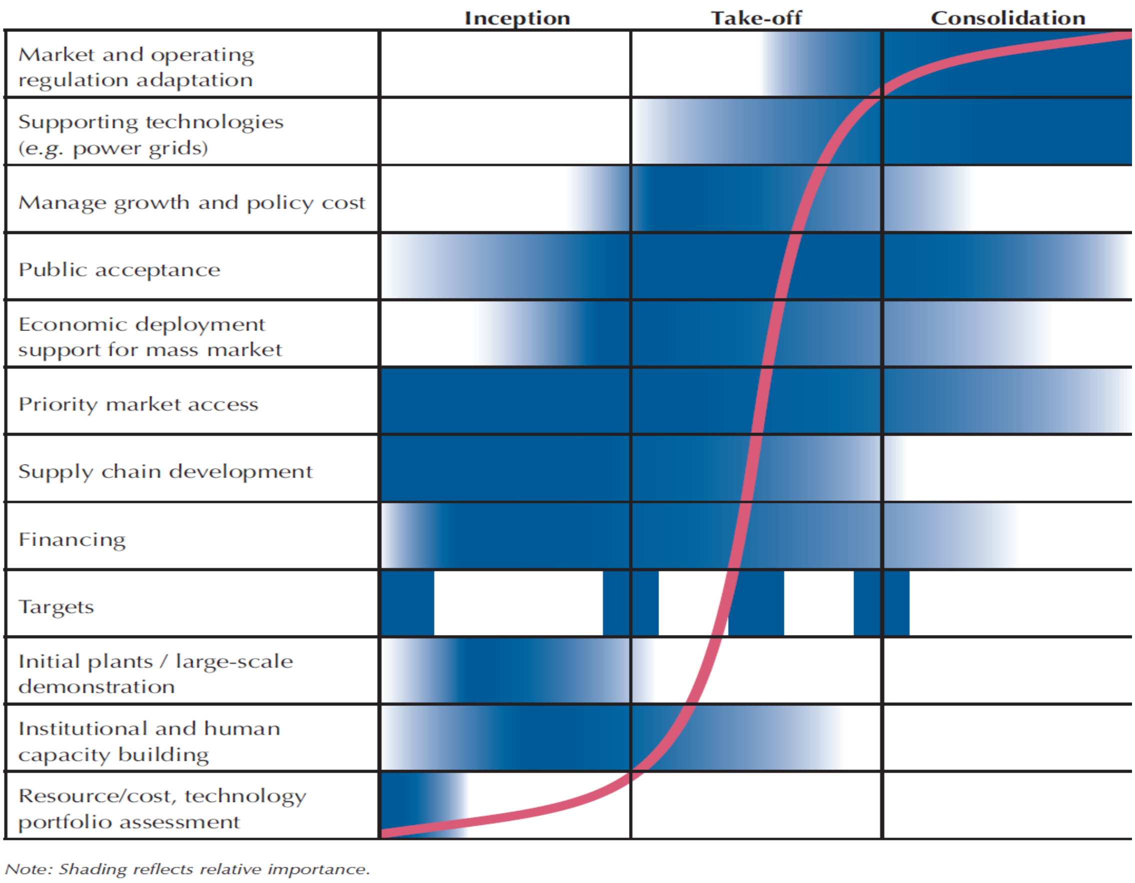
The three phases are:

- An *inception phase*, when the first examples of technology are deployed under commercial terms. Costs at this stage may be relatively high, so the desirable deployment levels may be constrained to manage overall policy costs.
- A *take-off phase*, when the market starts to grow rapidly. During this phase the costs are expected to fall, and the aim is to manage the incentives and deployment levels so as to secure deployment in a managed way as far as overall policy cost is concerned. If costs fall, more widespread deployment can be promoted.
- A *market consolidation phase*, where deployment grows toward the maximum practicable level.

Through these phases, new challenges evolve as RE market growth rates accelerate and penetration levels increase correspondingly. In general terms, as market development progresses, certain deployment barriers may occur, and consequently certain issues require policy intervention (Figure 1). The technologies considered in this report are at the start of the take-off stage, although both technologies considered in this report have themselves different maturity levels, with wind offshore being in this context at a more advanced stage than CSP.

Regarding CSP, whereas the first commercial-size plants have been constructed in and outside the EU, development on a very large-scale, as experienced by the PV and wind on-shore energy sectors, has yet to commence. Wind offshore has experienced three times as much deployment as CSP in the EU. Member States' NREAPs clearly show a stronger role for offshore wind energy in reaching the 2020 RES targets compared to CSP.

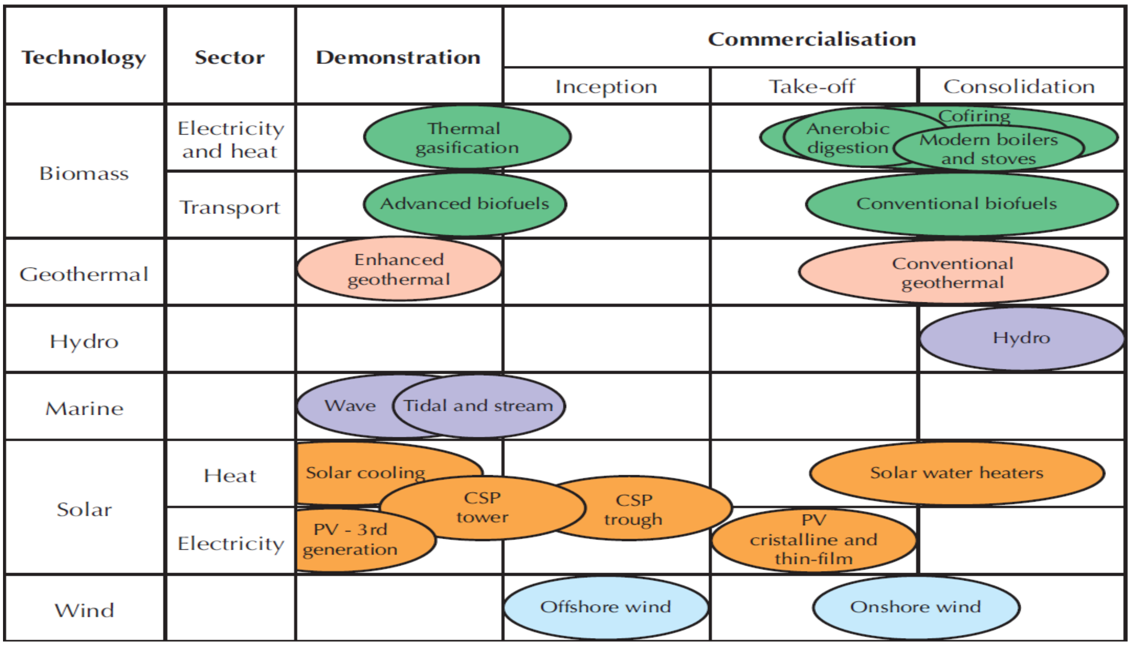
Figure 1: Deployment journey.



Source: IEA, 2011.

RETs occupy different positions along the policy deployment journey, taking into account their status and the principal barriers that they face. An IEA report on RETs deployment (IEA 2011) located these technologies in the initial stages of the commercialization phase (Figure 2). Since these SMTs by definition are highly dynamic they can be expected to have advanced beyond the inception to the early take-off stage.

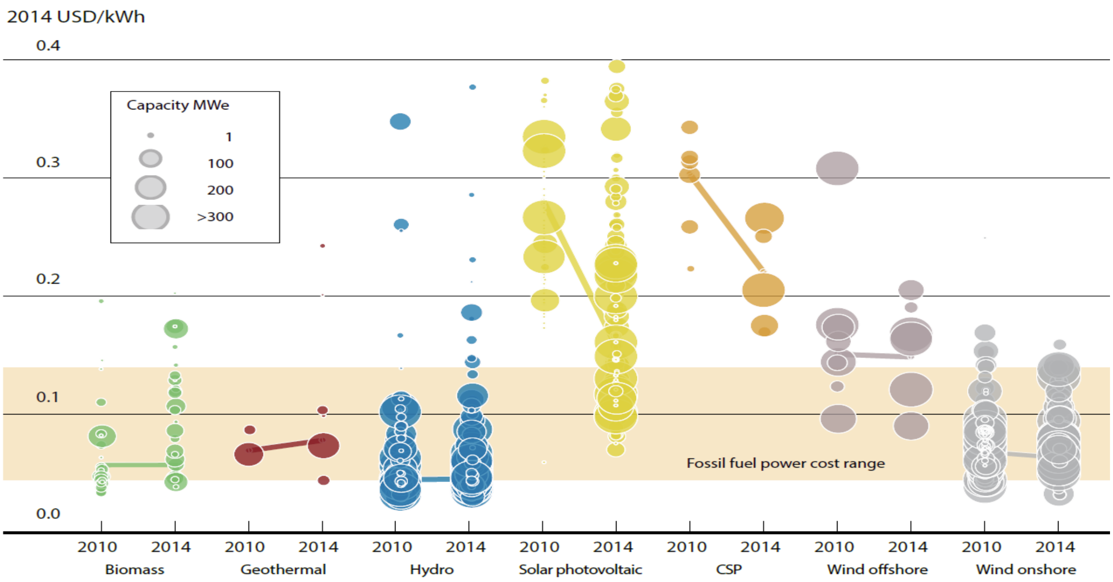
Figure 2: Maturity of selected RE technologies.



Source: IEA (2011).

Three commonalities for both SMTs considered in this report are that their costs are still comparatively higher than for other RETs, that their costs in the EU are higher than elsewhere and that these costs have significantly been reduced in recent years (figures 3 and 4). Nevertheless, the costs of CSP (in terms of LEC) are substantially higher than for wind offshore. The high costs and their prospects for further reduction are analysed in the next sections.

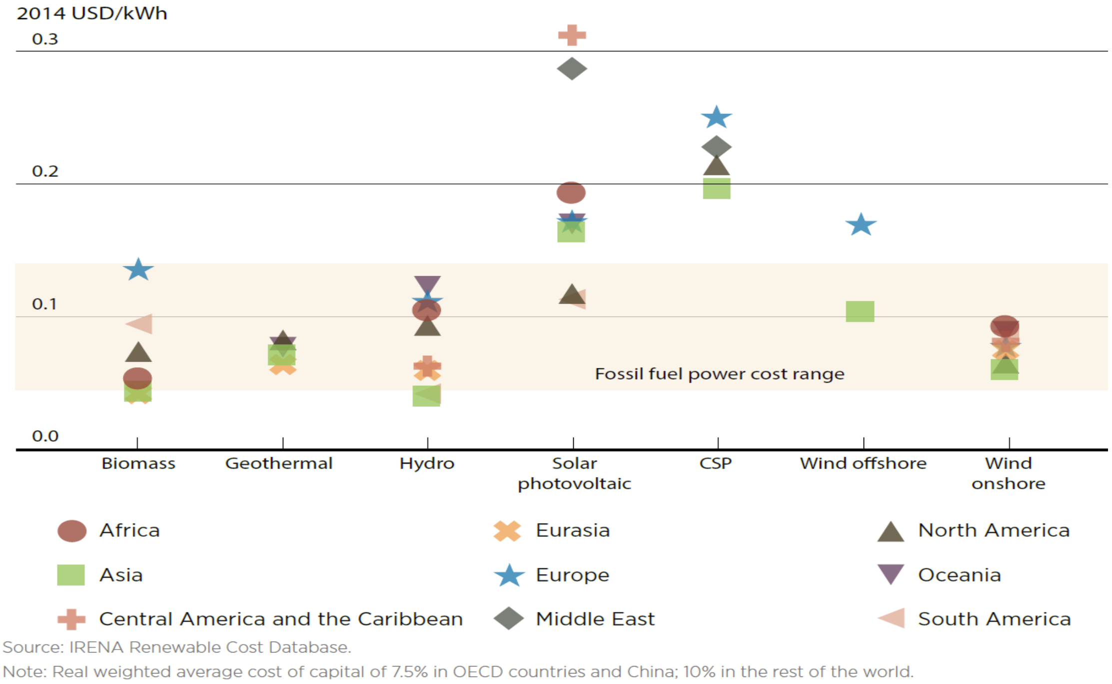
Figure 3: Levelised cost of electricity from utility-scale renewable technologies, 2010 and 2014.



Source: IRENA (2014).

Note: Size of the diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the Y axis. Real weighted average cost of capital is 7.5% in OECD countries and China; 10% in the rest of the world. LCOE results are calculated using a fixed assumption of a cost of capital of 7.5% real in OECD countries and China, and 10% in the rest of the world unless explicitly mentioned.

Figure 4: Weighted average cost of electricity by region for utility-scale renewable technologies, compared with fossil fuel power generation costs, 2013/2014.



Source: IRENA (2014).

The analysis of drivers and barriers is done in two steps. First, a desktop search of technical documents in the literature on the drivers and barriers to the two technologies has been carried out. Those barriers have been considered and included in an initial document. In a second stage, we have interviewed relevant stakeholders (energy experts and people from the sector) in order to gain further insights on those barriers and identify possible policy alternatives to tackle them. Six semi-structured interviews were carried out for CSP between April and May 2016, lasting between 30 and 90 minutes. Two of these interviews were carried out personally, the other two were telephone interviews. The stakeholders interviewed included a manager of a CSP plant, representatives from two firms investing in the technology and three researchers from public institutions involved in CSP research. Interviewees were asked to rank the different drivers (section 3.1.1), barriers (section 3.1.3) and policies (section 4) according to their relevance in influencing CSP deployment. Correspondingly, 4 semi-structured interviews were also executed covering OWE. The interviews were conducted in May and June 2016. One hour was allocated for each interview, conducted via phone. The phone interviews were structured in the following manner: findings were presented by the interviewer on key drivers and barriers (sections 3.1.2.3 and 3.2.2.4), followed by views and feedback from the interviewee. The phone was completed with feedback on key policy improvements necessary to push OWE deployment further (section 4).

The rest of this document is structured as follows. Section 2 provides a brief description of CSP and wind offshore technologies, including their comparative costs and potential evolution, and their expected contribution to the EU energy mix. Section 3 is dedicated to the analysis of the drivers and barriers. Based on this analysis, a proposal for policy portfolios is made in section 4. Section 5 concludes.

2 CSP and wind offshore: two still maturing technologies

2.1 Brief description of the technologies

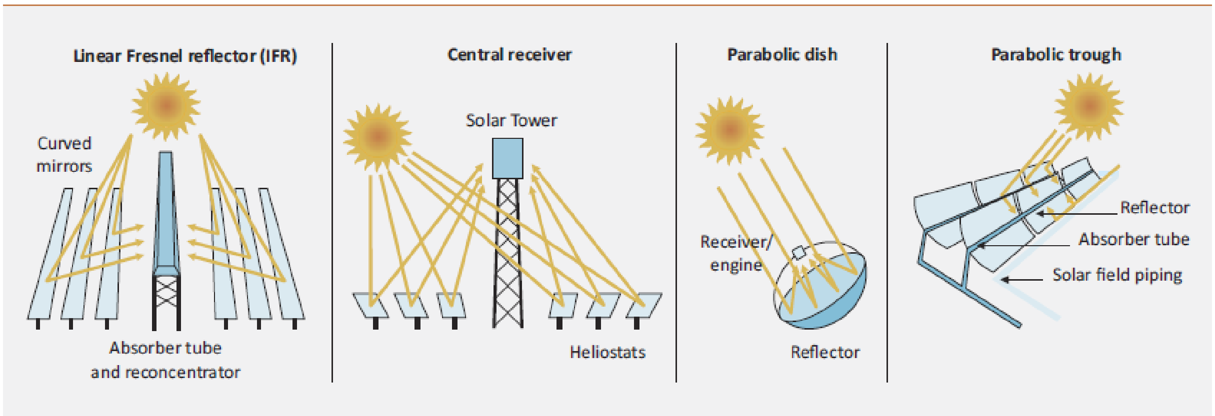
2.1.1 CSP

In Solar Thermal Electricity (STE) technology, also called Concentrated Solar Power (CSP), mirrors concentrate solar energy onto a heat medium, which is then used to drive a conventional turbine. Designs either concentrate to a few hundred degrees (Parabolic/Fresnel designs) or to a maximum temperature for steam power cycles in power tower designs (around 600 degrees Celsius) (IRENA 2014).

There are four CSP plant variants, namely: Parabolic Trough (PT), Fresnel Reflector (FR), Solar Tower (ST) with a central receiver and Solar Dish (SD), which differ depending on the design, configuration of mirrors and receivers, heat transfer fluid used and whether or not heat storage is involved. The first three types are used mostly for power plants in centralised electricity generation, with the parabolic trough system being the most commercially mature technology. These technologies differ with respect to optical design, shape of receiver, nature of the transfer fluid and capability to store heat before it is turned into electricity (figure 5 and tables 1 and 2). They also differ with respect to their maturity levels. Solar dishes are more suitable for distributed generation (IEA 2013).

While PT and FR plants concentrate the sun's rays on a focal line and reach maximum operating temperatures between 300-550°C, ST and SD plants focus the sunlight on a single focal point and can reach higher temperatures. PT is currently the most mature and dominant CSP technology. In PT plants, synthetic oil, steam or molten salt are used to transfer the solar heat to a steam generator, and molten salt is used for thermal storage. ST is presently under commercial demonstration, while FR and SD are less mature (IEA 2013).

Figure 5: Main CSP technologies.



Source: IEA (2014b).

Table 1: The main CSP technology families.

Focus type / *Receiver type*	***Line focus*** *Collectors track the sun along a single axis and focus irradiance on a linear receiver. This makes tracking the sun simpler.*	***Point focus*** *Collectors track the sun along two axes and focus irradiance at a single point receiver. This allows for good receiver efficiency at higher temperatures.*
Fixed Fixed receivers are stationary devices that remain independent of the plant's focusing device. This eases the transport of collected heat to the power block.	Linear Fresnel reflectors	Towers
Mobile Mobile receivers move together with the focusing device. In both line focus and point focus designs, mobile receivers collect more energy.	Parabolic troughs	Parabolic dishes

Source: IEA (2014b).

Table 2: A comparison of CSP technologies.

	Parabolic trough	Solar tower	Linear Fresnel	Dish-Stirling
Maturity of technology	Commercially proven	Commercially proven	Early commericial projects	Demonstration projects
Operating temperature (°C)	350-400	250-565	250-350	550-750
Collector concentration	70-80 suns	> 1 000 suns	> 60 suns (depends on secondary reflector)	up to 10 000 suns
Receiver/absorber	Absorber attached to collector, moves with collector	External surface or cavity receiver, fixed	Fixed absorber, no evacuation secondary reflector	Absorber attached to collector moves with collector
Application type	On-grid	On-grid	On-grid	On-grid/Off-grid
Suitability for air cooling	Low to good	Good	Low	Best
Storage with molten salt	Commercially available	Commercially available	Possible, but not proven	Probably, but not proven

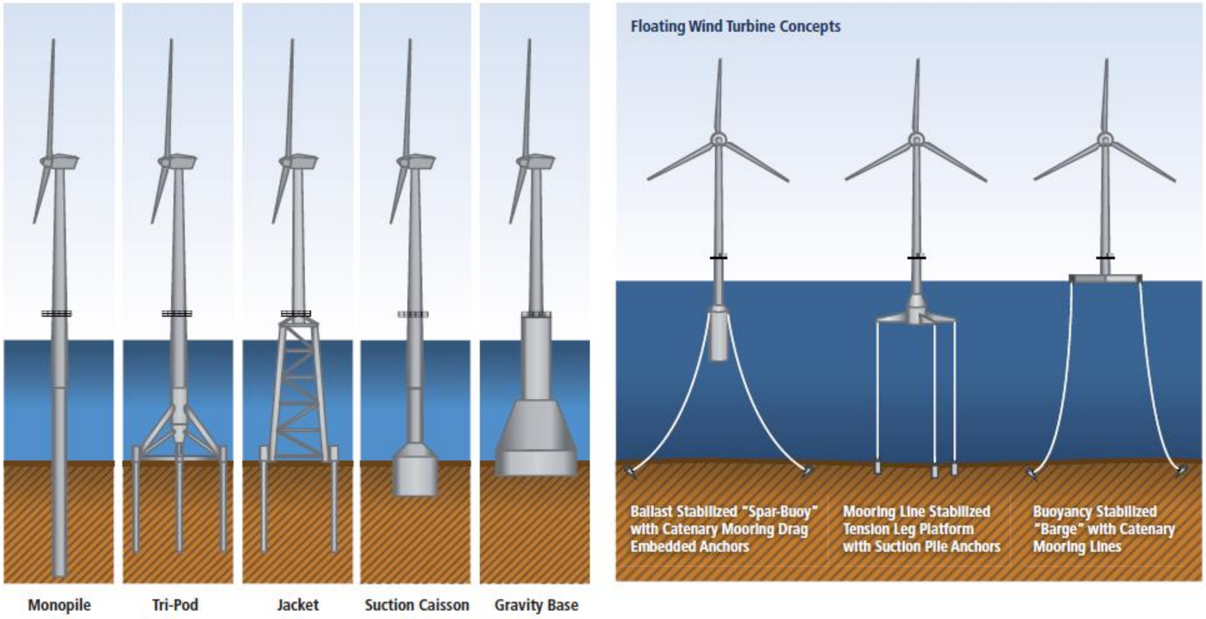
Source: IRENA (2015).

2.1.2 Wind offshore

Offshore wind technology has come a long way, particularly in the last decade. Whilst the fundamentals of offshore wind technology are similar to those of onshore, there are some very important differences, such as the methods of installation, operation and services. These differences are largely due to more challenging conditions at sea and access to the turbines, as well as the type of foundations required, which largely depend on the nature of the sea bed and the sea depth. There is no single foundation that suits all types of sea beds and sea depth.

The recent growth in offshore wind deployment has been accompanied by several innovations and technical improvements. Figure 6**Error! Reference source not found.** shows alternative designs concerning the foundation of offshore wind turbines. To date, the most common substructure used in Europe are monopiles (78.8%: 2301 of the 2920 European offshore wind foundations at the end of 2014), followed by gravity-based foundations (10.4%), jacket foundations (4.7%), tripods (4.1%) and floating structures (0.7 %). At the current technology status, notably in relatively shallow waters, monopiles are the lowest-cost foundation solution (EWEA, 2015).

Figure 6: Offshore wind turbine foundation designs.

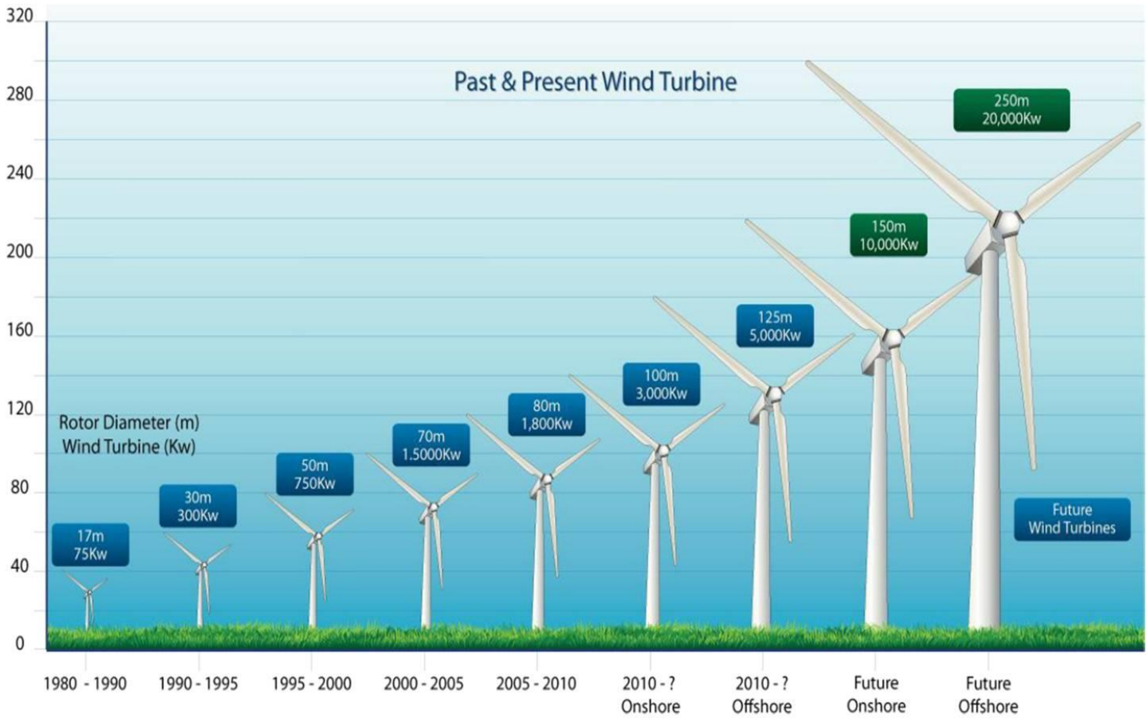


Source: Wiser et al, Wind Energy. In IPCC Special Report on Renewable Energy Sources and Climate Change (2011).

The offshore wind turbine is very similar to the onshore turbine, with three blades. Turbines at sea are generally larger in hub height, rotor diameter and capacity. Recently commissioned offshore wind parks mostly consist of the 3.6MW Vestas wind turbine. However, a few parks have installed 5MW turbines. Today's installed towers are typically 80-100 meters tall and occasionally up to 135 meters tall (Ellern 7.5 MW Enercon Turbine).

Over the last few years, important developments have taken place on the size of the offshore wind turbine. New developments are gradually becoming available (albeit not commercially), for example, Mitsubishi 7MW Sea Angel turbine or the Areva/Gamesa 8MW turbine.

Figure 7: Evolution of wind turbines.



Source: Schlumberger (https://www.sbc.slb.com/SBCInstitute/Publications/Wind.aspx, accessed 7 May 2016)

An important cost component to offshore wind parks is the grid infrastructure at sea (including offshore sub-stations and connections points to onshore grid). Transportation of the power from the wind farm at sea to the existing grid onshore consists of four main elements[1]:

- A transformer platform which collects the power from the wind farm and increases the voltage
- A sea cable which transports the power to shore
- A cable station onshore; and
- A land cable which transports the power to an existing transformer station onshore.

A key cost driver is distance to shore, i.e. the further from shore the offshore park is located the higher the grid connection costs. The connection of large wind farms to the electrical network is a challenge for transmission system operators and for wind farm developers. Main intention of the grid connection is that the wind farm and the electrical network operate in a safe and reliable manner. This entails a connection via three-phase high voltage AC (HVAC) cables and a connection via high voltage direct current (HVDC) cables.

Future offshore wind farms are expected to be built farther away from shore and have larger capacities than today. This leads to new challenges related to grid connection. At distances longer than roughly 100 km, HVDC transmission is preferred over AC transmission due to large charging currents in AC-cables. Industry is stretching the distance at which HVAC transmission systems can be used and reducing hardware requirements. It is also developing more effective and flexible HVDC solutions (KIC InnoEnergy, 2015b).

1 www.ens.dk

2.2 Current and expected diffusion of the SMT in the 2030 timeframe

2.2.1 CSP

CSP has experienced a substantial increase in deployment in the last years worldwide, although starting from a very low base. According to the IEA (2014b), total installed capacity in solar thermoelectric (STE) at the end of 2013 amounted to 3.6 GW, up from 600 at the end of 2009. This growth has been concentrated in Spain (2304 MW) and the United States (900 MW), but the technology is also being deployed in other countries, including the United Arab Emirates, India, Morocco, South Africa, Algeria, Australia, Egypt, Italy and Iran. Despite around 15 solar tower projects or more in operation, the current CSP market is dominated by the parabolic trough technology, both in terms of number of projects and total installed capacity (around 85% of capacity) (IRENA 2015).

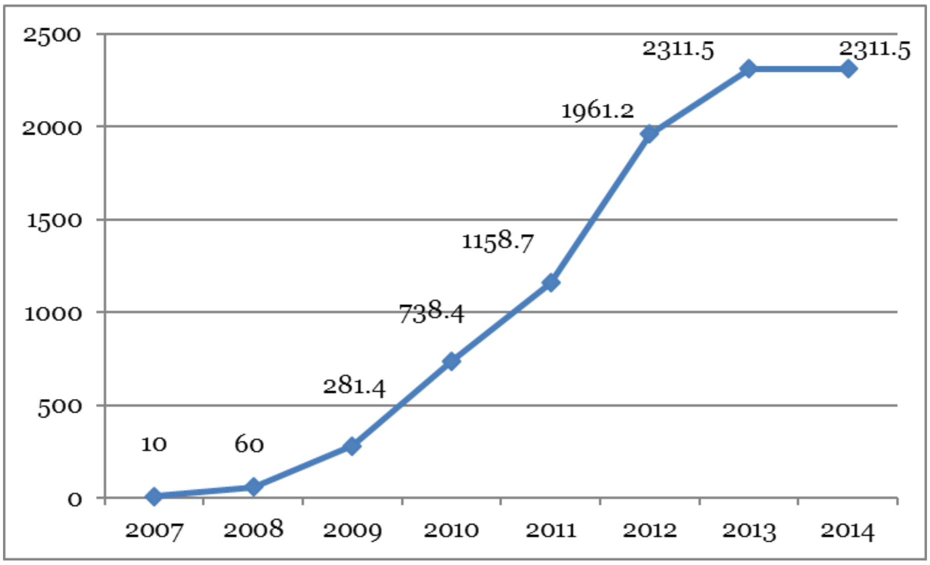
The increase in deployment in the EU has been significant (figure 8), mostly using the parabolic trough technology. In the next decade, the global CSP market is expected to develop with a higher share of tower, Fresnel and dish collectors at the expense of trough (IRENA 2014). The total installed CSP capacity to date in Spain represents 99.7% of the total installed capacity in the EU (EurObserv'ER 2015). However, this is likely to change in the future, since only 50 MW are under construction or at an advanced stage of development and Italy seems to have taken over (table 3), with many projects under development (see Annex I for further details on each project).

Table 3: CSP in operation and under development in the EU.

	In operation		Under development	
	Capacity (MW)	Nº of projects	Capacity (MW)	Nº of projects
Spain	2303.9	50	50	1
Italy	5.35	2	361.3	17
Germany	1.5	1		
France	0.75	2	21	2
Cyprus			50.8	1
Greece			125	2
TOTAL EU	2311.5	55	628.1	23

Source: Own elaboration based on EurObserv'ER (2015).

Figure 8: Evolution of CSP in the EU (MW).



Source: EurObserv'ER (2015).

The future deployment of CSP around the world looks bright according to different publications. These focus on the 2030 and 2050 timeframes. According to IRENA (2014), in 2030, CSP would reach 52GW in the reference scenario and 83 in the so-called Remap 2030 scenario. However, in its WEO report, the IEA (2012) expected a much lower amount of CSP capacity being installed (110 GW in the 450 scenario).

The analysis of the IEA (2014a) shows that STE could represent as much as 11% of electricity generation in 2050 in the 2DS hi-Ren scenario[2], and 954 GW of installed capacity (table 4). In its STE technology roadmap (IEA 2014b), the IEA updates those figures upwards, expecting 982 GW in 2050, with only 28 GW of those being deployed in the EU. These numbers are in line with the STE/CSP European industry association ESTELA, which expects a worldwide diffusion of 1080 GW in 2050, 90 GW of which will be in Southern Europe (Estela 2014).

Table 4: STE in different scenarios in 2030 and 2050.

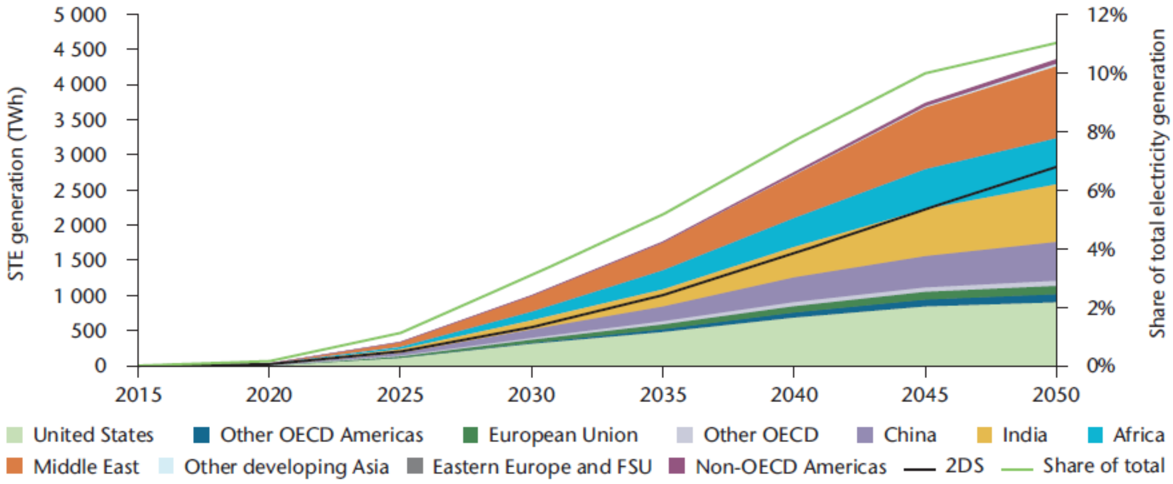
	6DS		4DS		2DS		2DS Hi-Ren	
	2030	2050	2030	2050	2030	2050	2030	2050
STE generation (TWh)	92	359	147	796	554	2835	986	4186
STE (%)	0.3	0.7	0.4	1.8	1.7	7.1	3	11
STE capacity (GW)	26	98	40	185	155	646	252	954

Source: IEA (2014a).

2 The 6°C Scenario (6DS) is a base-case scenario, in which current trends continue. It projects that energy demand would increase by more than two-thirds between 2011 and 2050. Associated CO2 emissions would rise even more rapidly, pushing the global mean temperature up by 6°C. The 2°C Scenario (2DS) sees energy systems radically transformed to achieve the goal of limiting the global mean temperature increase to 2°C. The High-Renewables Scenario (hi-Ren Scenario) achieves the target with a larger share of renewables, which requires faster and stronger deployment of PV, as well as wind power and STE, to compensate for the assumed slower progress in the development of CCS and deployment of nuclear than in 2DS (IEA 2014a).

According to the IEA (2014a, 2014b), growth until 2050 is geographically concentrated in the 2DS scenario, with Africa and the Middle East being followed by the US, and India and China. The share of the EU and other OCDE countries is negligible (figure 9). Although parabolic trough technology currently dominates, its share of total installed capacity will decline slowly in the near future, as around one-third of the capacity of plants currently under construction are either solar tower projects or linear Fresnel systems (IRENA 2015).

Figure 9: Regional production of STE envisioned in the IEA Roadmap.



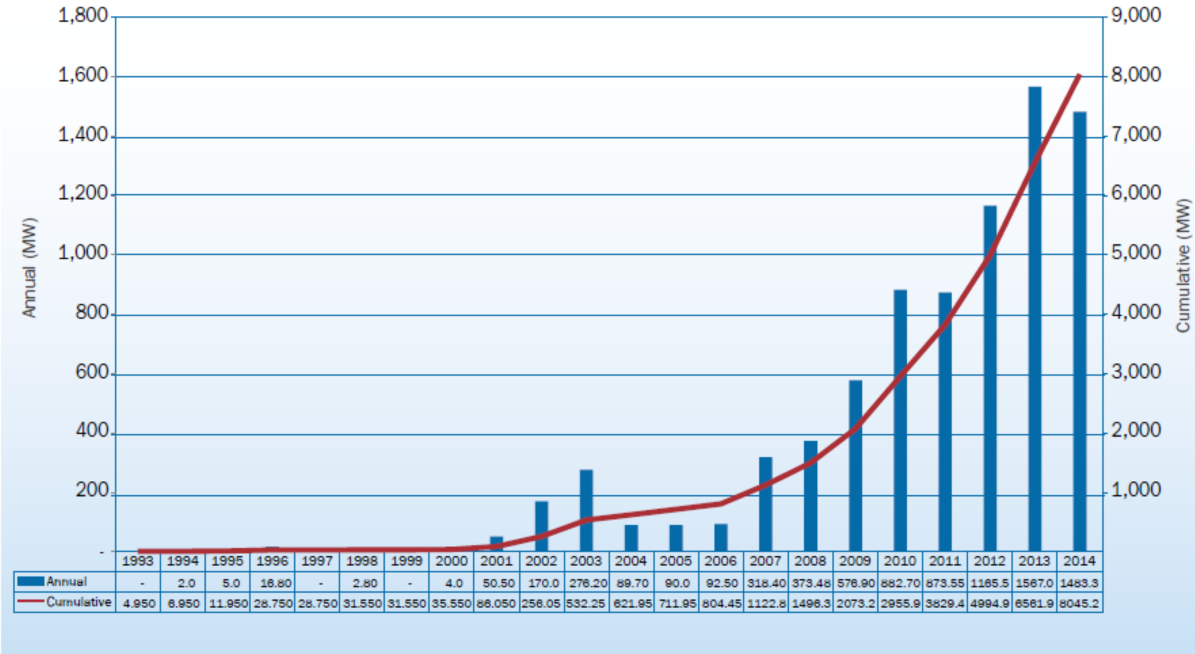
Source: IEA (2014b).

According to the NREAPs, installed capacity in the EU by 2020 will reach 6765 MW (4800 in Spain, 600 in Italy, 540 in France, 500 in Portugal, 250 in Greece and 75 in Cyprus), 20 TWh of output are expected. However, the economic and political environment has cast doubt on this roadmap. Most of the countries that set objectives are way off targets, and if no significant political change is announced within the next two to three years, the sector will only reach 3131MW in 2020 (EurObserv'ER2015, p.8). In fact, 3526MW were expected for 2015 in the NREAPS, and only 2312.5 MW will materialize.

2.2.2 Wind offshore

Offshore wind has been experiencing a rapid global growth in recent years. Figure **10 Error! Reference source not found.**below shows the annual and cumulative evolution of installed offshore wind capacity in the EU from 1993 to 2014. After a long incubation period offshore wind really took off as from 2007. Installed offshore wind capacity grew to about 8 GW in this time span. According to EWEA, there is close to 10.4 GW of fully grid connected offshore wind capacity in European waters as of end of June 2015.

Figure 10: Evolution of annual and cumulative installed offshore wind capacity in the EU.



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Annual	-	2.0	5.0	16.80	-	2.80	-	4.0	50.50	170.0	276.20	89.70	90.0	92.50	318.40	373.48	576.90	882.70	873.55	1165.5	1567.0	1483.3
Cumulative	4.950	6.950	11.950	28.750	28.750	31.550	31.550	35.550	86.050	256.05	532.25	621.95	711.95	804.45	1122.8	1496.3	2073.2	2955.9	3829.4	4994.9	6561.9	8045.2

Source: EWEA, key trends and statistics 2014 (2015).

The three leading EU Member States for off-shore wind are the UK (4494 MW installed end of 2014), Germany (1271 MW) and Denmark (1049), with also significant installed capacity in Belgium (712 MW), the Netherlands (247 MW) and Sweden (212 MW). So far, most of European offshore wind development has taken place in the North Sea (63.3% of total capacity installed in Europe), whilst the Atlantic Ocean (22.5%) and the Baltic Sea (14.2%) are hosting sea regions of importance as well. As per end of 2012, 420 MW offshore wind capacity was installed outside of the EU.[3] China accounted for the lion's share with 390 MW, whilst Japan (25 MW) and South Korea (5 MW) made up the remainder. India has planned to install offshore wind capacity in the near future as well.

Mainly because of the protracted economic downturn in Europe, both electricity demand and wind power generation projections in the EU have been revised downward. To date, the European Commission projects gross final electricity consumption in the EU at 2956 TWh in 2020. EWEA projects in its central scenario total wind power generation in the EU in 2020 at 441TWh (bandwidth 379-500TWh), with offshore wind accounting for 86TWh (bandwidth 72-102TWh).[4] If EWEA's central scenario and the Commission projections prevail, by 2020 offshore wind will cover 2.9 % of gross final energy consumption in the EU with total wind power accounting for 14.9%. The installed base for offshore wind in 2020 is projected by EWEA to total 23.4 GW (bandwidth 20-28 GW). In the decade of the 2020s offshore wind is poised to grow appreciably faster than wind onshore and renewables as a whole and may well account for double-digit percentage points of the EU gross final electricity consumption by 2030.

According to IEA's 2013 Wind Energy Technology Roadmap, with strong support in some countries, offshore wind progresses significantly to 2018, but its viability over the medium term ultimately depends on tackling technical and financial challenges. By 2018, it should reach 28 GW globally, with Europe (led by the United-Kingdom, then Germany and Denmark) driving much of the growth, representing almost two-thirds of total cumulative capacity

3 http://www.gwec.net/wp-content/uploads/2012/06/Offshore_Global-Cumulative-Offshore-Installed-Capacity-in-20121.jpg

4 (EWEA, 2014)

by 2018. China (28%), the United States, Japan and Korea account for the rest. By 2018, offshore wind should deliver 76 TWh of electricity globally – a third of which from the United Kingdom, followed by China.

3 Drivers and barriers to the uptake of CSP and offshore wind

Drivers and barriers to SMTs are different sides of the same coin. They can broadly be called "determinants". The literature generally uses the term "barriers", whereas a focus on "drivers" is missing, with some exceptions (see de Río 2012). There is an abundant literature on the classification of barriers to renewable energy technologies (see, among others, del Rio 2012, Painuly 2001, Mitchell et al 2011, IEA 2011.

IEA (2011) broadly distinguishes between two types of barriers to deployment:

- Techno-economic barriers relate to the direct costs of a certain technology in comparison to competing technologies, given the internalisation of all external costs and ideal framework conditions.
- Non-economic barriers relate to factors that either prevent deployment altogether (no matter how high the willingness to pay) or lead to higher costs than necessary or distorted prices. These barriers can be differentiated further:
    - Regulatory and policy uncertainty barriers, which relate to bad policy design, or discontinuity and/or insufficient transparency of policies and legislation.
    - Institutional and administrative barriers, which include the lack of strong, dedicated institutions, lack of clear responsibilities, and complicated, slow or non-transparent permitting procedures.
    - Market barriers, such as inconsistent pricing structures that disadvantage renewables, asymmetrical information, market power, subsidies for fossil fuels, and the failure of costing methods to include social and environmental costs.
    - Financial barriers associated with an absence of adequate funding opportunities and financing products for renewable energy.
    - Infrastructure barriers that mainly centre on the flexibility of the energy system, e.g. the power grid, to integrate/absorb renewable energy.
    - Lack of awareness and skilled personnel relating to insufficient knowledge about the availability and performance of renewables as well as insufficient numbers of skilled workers.
    - Public acceptance and environmental barriers linked to experience with planning regulations and public acceptance of renewable energy.

Key drivers to the deployment of CSP and wind off-shore are discussed in section 3.1, whereas section 3.2 focuses the barriers.

3.1 Key drivers

3.1.1 CSP

3.1.1.1 Techno-economic drivers

-High technological dynamism. CSP, with a long development journey, has already reached the commercial stage. However, it is only at the beginning of its commercial deployment in terms of installed capacity, with only wave and ocean technologies having less installed capacity (ALINNE 2015). Therefore, significant improvements and cost reductions can be expected in the future, as the industry scales up, operating experience improves, technology improvements are deployed and a larger and more competitive supply chain develops, both locally and globally (IRENA 2015). Within the different CSP technologies, there are different maturity levels, with parabolic trough and solar tower being commercially proven, only early commercial projects for linear Fresnel and demonstration projects for Dish-Stirling (IRENA 2015). For all three predominant types of CSP technologies

– parabolic troughs, LFRs and towers –novel optic designs are being considered, as well as new mirror materials and receiver designs. Tower designers are also exploring choices relative to the type of receivers (cavity or external), the number and size of heliostats, the number of towers associated with each turbine, and the size and shape of solar fields (IEA 2014b).

-*Different designs and technological competition*. Innovation theory predicts that at the early stage of a technology, different designs compete between each other. This is also the case with CSP. The sector is still commercially validating the various solar thermal processes. The technologies are still competing with one another and it is very hard to predict which technology will come out on top (EurObserv'ER 2014). A broad set of plant technologies and designs (troughs, DSG towers, molten-salt (IEA) towers and LFR), including larger plants (up to 250 MW), have been built in a greater number of markets in the last years (IEA 2014b). Up to this moment one design has been dominant (trough) but, as mentioned in section 2, solar towers are expected to capture an increasing share of the market in the future.

-*Technological development in niches*. As also predicted by innovation theory, SMTs benefit from technological improvements as a result of capturing market niches. Niches provide a space for technologies to improve their performance through learning by use and interacting and through economies of scale. In addition to renewable heat and power generation concentrating solar plants have other economically viable and sustainable applications, such as co-generation for domestic and industrial heat use, water desalination and enhanced oil recovery in mature and heavy oil fields (IEA 2013). Experts consulted in REN21 (2013) stressed that part of CSP technology evolution will take the form of novel applications (especialised demands), some of which are emerging already. Such applications include: (1) managing grid variability and providing peak power using thermal energy storage embedded within the CSP plant; (2) dedicated CSP plants powering desalination plants in coastal areas; (3) embedded CSP plants in industrial facilities to provide power and industrial process heat; (4) pre-heating feed-water for a coal power plant to reduce coal consumption; (4) integration with combined-cycle natural gas plants (already occurring); and (5)producing gas or liquid fuels including hydrogen; (6) co-generation of heating, cooling and power; (7) production of synthetic fuels (e.g. syngas), (8) enhanced oil recovery and refineries (REN21 2013, IEA 2015, IEA 2013). There are niches in innovation with other horizontal solar technologies (materials, hybridization, storage, manageability etc. (ALINNE 2015).

-*Hybridisation*. Innovation theory predicts that the drop-in features of new, emerging technologies clearly facilitate their introduction in a market and techno-institutional context adapted to existing technologies (Kemp 1994). In the case of CSP, hybridization with other technologies represents a key drop-in characteristic, being both an advantage of and a niche market for these technologies. CSP plants can easily be integrated into existing biomass-fired and fossil fuel-based power plants that use conventional steam turbines to produce fully dispatchable electricity, whereby the part of the steam produced by the combustion of fossil fuels is substituted by heat from the CSP plant (IEA 2013, IEA 2014b). In this case, the solar field provides steam to the thermodynamic cycle of the conventional power plant. Projects based on this concept are in operation in Algeria, Australia, Egypt, Italy and the United States (IEA 2013, IRENA 2014). The economics are better than those of stand-alone CSP plants, because power blocks and BOP are already paid for. Solar fields bring mid-temperature heat into coal plants, which spares high-temperature heat from being distracted from the turbine, thus operating with higher efficiency. Such hybridisation could be a step towards bringing down the costs of solar technologies with larger deployment numbers and related learning effects (IEA 2014b).

-*Significant cost reductions.* Since one main barrier to the diffusion of CSP is its high costs (see next section), cost reductions are obviously a main driver for this technology. Given the CSP capacity under construction or announced, substantial LCOE reductions (i.e. between 30-50%) are expected for both PT and ST plants (IEA 2013). Several predictions of cost reductions are available in the literature (table 5).

Table 5: Cost reductions expected for CSP (LCOE).

Reference	Cost reductions	Comments
ALINNE (2015)	150 €/MWh in 2014, 100 €/MWh in 2020, 70 €/MWh in 2030.	CSP plants in Spain. Similar predictions by ESTELA for 2020.
IRENA (2014)*	• 2014 ranges: PT (no storage): 0.18-0.29 $/kWh PT (6-hour storage): 0.175-0.27 $/kWh ST (6-15 hour storage): 0.17-0.26 $/kWh • 2025 ranges: PT (no storage): 0.14-0.19 $/kWh PT (6-hour storage): 0.13-0.17 $/kWh ST (6-15 hour storage): 0.12-0.16 $/kWh	2025 timeframe.
IEA (2014b)	• 2015 range: 158-263 $/MWh (without storage) and 146-213 (with storage). • 2020 range: 126-209 $/MWh (without storage) and 116-169 (with storage). • 2030 range: 93-156 $/MWh (without storage) and 86-126 (with storage). • 2050 range: 76-127 $/MWh (without storage) and 71-103 (with storage).	6-hour storage.

* PT = parabolic trough; ST = solar tower

The *learning* rate for CSP systems and components is highly uncertain given the early stage of deployment of CSP technology. Estimates of 8-10% based on other technologies are considered conservatively realistic (IEA 2013).

The IEA ETP (2010) "Technology Roadmap" already envisioned continued innovation in CSP though 2020, and a number of specific innovations during 2020–2030, including higher working temperatures (higher efficiency), larger storage capacities, supercritical plants, desalination by co-generation, and tower plants with air receivers and gas turbines. More recently, the IEA (2014b) suggests the existence of several paths for innovation. For all three predominant CSP technologies — PT, LFR and towers — novel optic designs are being considered, as well as new mirror materials and receiver designs. A few projects are experiencing with cheaper parabolic troughs of a laminated reflective components glued on aluminum sheets (Frazier, 2013). Tower designers are also exploring choices relating to the type of receivers (cavity or external), the number and size of heliostats, the number of towers associated with each turbine, and the size and shape of solar fields. New thermodynamic cycles (supercritical steam cycles, Brayton cycles with a gas turbine or supercritical CO2) can be envisioned. The next table lists some of the technological development milestones in the near, medium and long terms for CSP.

Table 6. Technology development actions and milestones for CSP.

	Time frames
1. Demonstrate using molten salts as HTF in linear systems (PT and LFR).) at large scale.	Complete by 2018
2. Develop light-weight, low-cost reflector optics.	Complete by 2018
3. Optimise heliostat size, solar field design, central receiver design, number of towers per turbine for 6 to 18 hours of storage.	Complete by 2018
4. Introduce supercritical steam turbines in CSP plants.	Complete by 2025
5. Increase the energy in receiver tubes with innovative non-imaging optics for linear systems.	Complete by 2020
6. Introduce innovative HTF: air, gas, nano-fluids in linear systems, fluoride liquid salts, air and particles in towers.	Complete by 2025
7. Introduce closed-loop multi-reheat Brayton turbines.	Complete by 2025
8.Develop and introduce supercritical CO_2 cycles.	Complete by 2030
9. Develop hybrid PV-CSP via spectrum-splitting or PV topping.	Complete by 2030
10. Intensify R&D on solar fuels (gaseous, liquid or solid).	2015-2050

Source: IEA (2014b).

A recent study by KIC InnoEnergy (2015a) shows that, for all CSP technology types, the impacts from STE technology innovations (excluding transmission, decommissioning, pre-FID risk, supply chain and finance effects) contribute an anticipated reduction in the LCOE of at least 23.6%. For parabolic trough, the main innovations are expected to be improved and cheaper manufacturing methods and automated production of components, advanced high-temperature working fluids, improved solar concentrator design, high-temperature receivers, tools for onsite checks of solar equipment, efficient plant monitoring and control with continuous onsite checks of solar equipment, software development at system level. For central receiver technologies, improved and cheaper manufacturing methods and automated production of components, improved solar concentrator design, software development at system level, efficient plant monitoring and control with continuous onsite checks of solar equipment, tools for onsite checks of solar equipment, design and coating of CR receivers and software development at component level. For linear Fresnel reflector, improved and cheaper manufacturing methods and automated production of components, tools for onsite checks of solar equipment, efficient plant monitoring and control with continuous onsite checks of solar equipment, advanced high-temperature working fluids, high-temperature receivers, software development at system level and advanced power cycles.

Some of the innovations will be related to the storage system. *Advanced thermal storage* systems include Lithium-based molten salts with high operation temperatures and lower freezing points, concrete or refractory materials at 400–500 ^oC with modular storage capacity and low cost (USD 40/kWh), phase-change systems based on Na- or K-nitrates to be used in combination with DSG; and cheaper storage tanks (e.g. single thermocline tanks), with reduced (30%) volume and cost in comparison with the current two-tank systems (IEA 2013). Some project developers seek to increase the electric conversion efficiency (mainly through higher temperatures) in order to downsize the solar field, which accounts for roughly half of the investment cost. This requires replacing the current heat transfer fluid of troughs (synthetic oil) with DSG or molten salts. The growing relevance of thermal storage favours using molten salts as both the heat transfer fluid and the storage medium (termed “direct storage”). Molten-salt towers are currently in operation in Spain and in the United States. Several companies are now developing the use of molten salts as a heat transfer fluid in linear systems, and have built or are building experimental or demonstration devices. One challenge is to reduce the parasitic loads required to keep the salts warm enough in long tubes at all times, including at night. Addressing this challenge is easier in towers because the central receiver is compact and can be drained by gravity; also, it is easier to keep salts hot in tanks (IEA 2014b).

On the other hand, there is a trend towards *upsizing* to reduce costs. Indeed, one of the main sector trends across all the major CSP technologies is the significant increase in project size to reduce production costs (EurObserv'ER 2014). Scaling up plants would allow reduction in the specific costs of turbines and BOP (IEA 2014b). An increased plant size reduces the costs associated with conventional components and systems, such as power block and balance of plant rather than the cost of the solar field, which depends primarily on industrial learning and large-scale production of components. The specific cost (USD/kW) of a PT plant with a 7.5 hour storage can be reduced by about 12% if the plant size is increased from 50 MW to 100 MW and by 20% if it is increased up to 200 MW (Kistner 2009, IEA 2013).

In addition, the economics of CSP plants are highly dependent on the costs of capital. CSP, as other RETs, is a capital-intensive technology and, thus, the high up-front costs represent a major barrier. The investment and financing costs account for more than 80% of the electricity cost, the rest being fixed and variable O&M costs (IEA 2013) and, thus, their reduction would significantly reduce the LCOE. According to IEA (2014b, p.24), "the most significant ways of reducing costs are lower capital expenditures and lower costs of capital".

-Higher value compared to other, intermittent renewable energy sources. While comparative higher capital costs make a technology obviously less attractive than its competitors, this is only one side of the economic equation. The other side is the benefits of the technology for the adopter. CSP has two very attractive features in this regard: adjustment to the demand profile and energy storage, which allows CSP to provide firm electricity, even when the sun does not shine.

1) Like PV, an advantage of CSP plants is that their output, when no thermal storage is used, follows closely the electricity and heat demand profile during the day in Sun Belt regions (IEA 2013).

2) Another very important advantage of CSP (over other, intermittent RES) is that it can integrate low-cost thermal energy storage to provide intermediate- and base-load electricity. This can increase significantly the capacity factor of CSP plants and the dispatchability of the generated electricity, thus improving grid integration and economic competitiveness of such power plants. Although CSP plants with thermal energy storage tend to have higher investment costs, they allow higher capacity factors, dispatchability, contribute to grid balancing, spinning reserve, and ancillary services, and typically have lower LCOEs (particularly for molten salt solar towers) (REN21 2013). They also have the ability to shift generation to when the sun is not shining and/or the ability to maximise generation at peak demand times (IRENA 2015, IEA 2014b). Therefore, the thermal storage capability of CSP plants not only increases their value, it also reduces the cost of electricity. There is a growing trend for the CSP projects under construction to include storage systems, which will be the norm for this type of projects in the future (EurObserv'ER 2014). This advantage will only gain in importance as variable renewable energy sources such as PV and wind power increase their shares of global electricity (IEA 2014b).

-Industry consolidation (mergers and acquisitions) and vertical integration. This phenomenon observed in the literature on innovation can also apply to the CSP sector. In parallel to the evolution of technology (and affected and affecting this process) is a consolidation of the sector, which leads to concentration and vertical integration phenomena. As noted by EurObserv'ER (2014, p.6), towards the end of 2005, the CSP industry entered a new phase when the pioneering firms were bought out by players with more financial clout or were consolidated with the arrival of new shareholders[5]. In addition, vertical integration has also been observed in the industry and can be also a feature of the sector in the near future[6].

5 Abengoa bought out Solúcar Energía and became Abengoa Solar, Areva Solar was created by the acquisition of Austra in 2010. BrightSource Energy, created in 2004, managed to gather more than 449 M€ of business funding from financial and strategic investors (op.cit. p.6).

6 In September 2013 Siemens CSP assets were acquired by Abengoa (the CSP sector's global leader), via its Rioglass Solar subsidiary that especialises in manufacturing parabolic mirrors. According to its CEO "the acquisition provided Rioglass Solar with a one-off opportunity to diversify its portfolio and consolidate its presence in the CSP market" (EurObserv'ER 2014, p.6).

CSP technology deployment has the potential for substantial local value addition through localisation of production of components, services and operation and maintenance, thus creating local development and job opportunities (IEA 2013). According to ALINNE (2015), thermoelectric plants are the ones creating more jobs since their construction to their start in operation. Each 50 MW plant employs an average of 10000 persons/equivalent/year during all the stages (from design, to component manufacturing and installation), half of these jobs are direct and half indirect. Furthermore, each 50 MW plant built in Spain employs 2000 persons on-site during the two years of construction. Once in operation, they require 50 permanent jobs. Indeed, according to Crespo (2014), local economic development (local content of STE plants -and corresponding contribution to the GDP) will be one of the main drivers behind the supporting policies in many countries of the sun belt. For countries which are net fossil fuel energy importers into their electricity sector, deployment of CSP could certainly look attractive to reduce this dependence. Note that those Southern European countries with relatively high DNI could also benefit from CSP deployment in terms of creating an industry which innovation theory and, in particular, the theory of lead markets, suggest that those countries which have been involved in the initial stages of a technology and, particularly, in its initial commercial deployment, enjoy a competitive advantage which facilitate their exports. This has certainly been the case in Spain. The country was involved in technological development of CSP since decades (Plataforma Solar de Almeria in the 1980s). The interaction between the public and private sector has led firms from this country (namely Abengoa) to be world leaders in the technology. The share of the country in total deployed capacity worldwide is high, but even higher are the prospects for exporting the technology around the globe, as it seems also to already have been the case.

3.1.1.2 Political drivers

Obviously, given the cost gap with their competitors, a main driver of CSP in the past has been support policies. CSP is still dependent on public support, which countries in Europe have been providing. Two main categories can be considered in this context: RD&D policies (at EU and MS level) and deployment support (at MS level). Both have led to technological improvements and cost reductions. Deployment support has led to technological improvements through learning effects and to cost reductions through learning effects and dynamic economies of scale. In the EU, national CSP deployment policies are likely to be relevant in the countries with CSP plants already constructed or under construction and which envisage CSP in their NREAPs (Spain, Portugal, Greece, Germany, Cyprus, France and Italy). The EU will also benefit from policies implemented around the world to support CSP, as this will allow technological improvements and cost reductions which will lead to either faster or less costly deployment of the technology in the EU. At present, many countries outside Europe have policies in place to support CSP deployment (e.g. Algeria, Australia, China, Egypt, India, Morocco, South Africa, United Arab Emirates and the United States).

The interviews among EU stakeholders confirm the relevance of all those drivers, but also suggest that some are more relevant than others. In particular, the policy drivers and the possibility to store energy are regarded as very relevant. Among the policy drivers, innovation support in the form of support for RD&D is ranked first, with deployment support being considered important, but less so (third position of all drivers). Second in importance is the driver “higher value compared to other, intermittent RES”. Significant cost reductions expected in the future comes fourth and complementarity and hybridisation come fifth. These refer to different drivers. While complementarity relates to the possibility that, in the future, PV and CSP may complement each other since the value of CSP will increase further as PV is deployed in large amounts, which shaves mid-day peaks and creating or beefing up evening and early morning peaks. Hybridisation refers to the possibility that CSP plants are integrated into plants that use conventional steam turbines to produce fully dispatchable electricity, whereby the part of the steam produced by the combustion of fossil fuels is substituted by heat from the CSP plant. Among the least relevant drivers, interviewees mention industry consolidation. This is the least relevant, followed by “different designs and technological competition” and “social acceptability for the technology”.

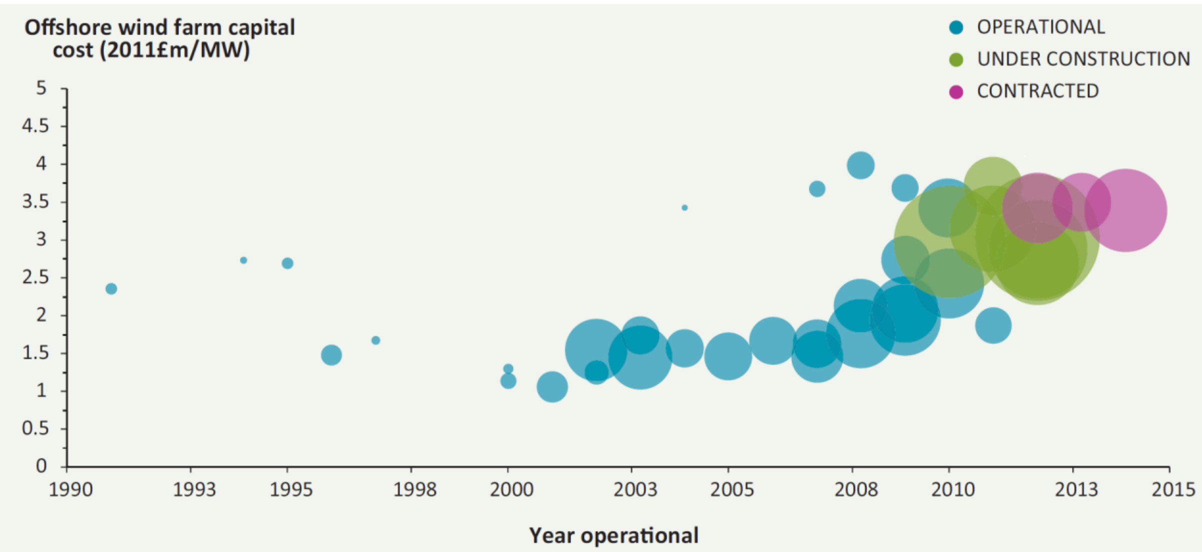
The expected cost reductions are surprisingly not a main driver of CSP. When asked about the sources of cost reductions in the short term, all of them, except research in the laboratory are considered as relevant. In particular, the greatest importance is attached to improvements in demonstration projects and learning effects, followed by dynamic economies of scale, reductions in the cost of capital and upsizing. The importance of those drivers of cost reductions changes substantially when considering more distant horizons, with research in the laboratory being considered the most relevant and learning effects and improvements in demonstration projects being the least relevant in the long-term.

3.1.2 Offshore wind

3.1.2.1 Techno-economic drivers

-Innovation and cost reduction. In the case of offshore wind, innovation has been a major factor behind cost reductions. There is also a large potential for innovation and cost-reductions in the future. Broadly from 2000 to 2010, technical improvements led to lower costs through technology learning, but also to the deployment of larger turbines in deeper waters. The difficult financing situation as from 2008 caused an overall trend of increasing capital costs. However, this trend seems to have stopped in the last few years, as can be seen in Figure 11**Error! Reference source not found.**.

Figure 11: Capital cost of offshore wind farms. The size of the bubbles reflects the size of the single projects.



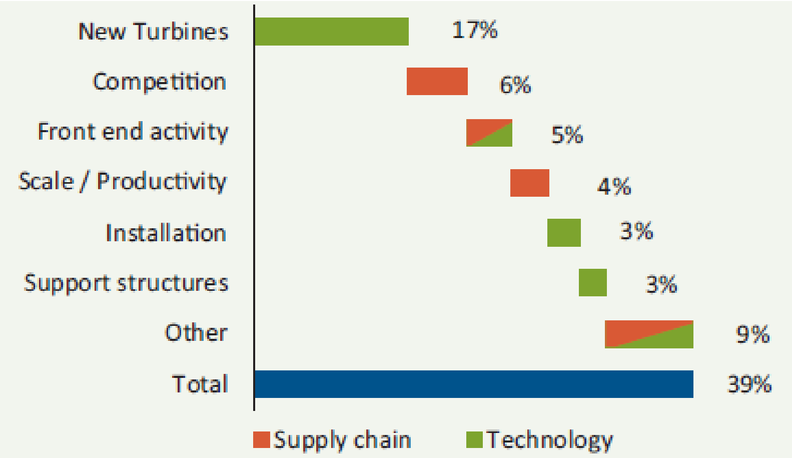
Source: Crown Estate Offshore Wind Cost Reduction Pathways Study (2012).

The LCOE from Offshore Wind has been decreasing steadily mainly due to increased turbine size and other technological improvements. Ambitious cost reduction aims have been set by some Member State governments for 2020, viz.: from 140 to 100 £/MWh in the UK[7], from 170 to 100 €/MWh in the Netherlands[8].

7 Crown Estate Offshore Wind Cost Reduction Pathways Study (2012)

8 ECN internal sources. The Dutch target allows for an anticipated important change in the Dutch regulatory framework concerning connection costs of offshore wind farms in the Dutch exclusive economic zone to the Dutch onshore transmission network. At present, the radial connections from Dutch offshore wind farms to the onshore transmission network falls under the responsibility of the wind farm operators. After implementation of the anticipated regulatory changes the Dutch TSO will assume the responsibility to expand his Dutch transmission network offshore to offshore hubs near (existing and planned) offshore wind parks. The costs concerned will be socialized. This is broadly in line with corresponding regulations in Germany.

Figure 12: Percentage reduction in LCOE of Offshore Wind project reaching FID between 2011-2020 in the UK.



Source: Crown Estate Offshore Wind Cost Reduction Pathways Study (2012).

A recent study by KIC InnoEnergy (2015b) shows that the impacts various technology innovations (excluding transmission, decommissioning, supply chain and finance effects) contribute an anticipated reduction in the LCOE in the order of 27%. The study looks at the transition from a typical wind farm with FID in 2014, which uses turbines with a rated power of 4 MW, to the use of 8 MW turbines for a project with FID in 2025. Furthermore, the study identified 50 technology innovations as having the potential to cause a substantive change in the design of hardware, software or process, with resulting quantifiable impact on the cost of energy.

The deployment of new technologies and steady improvements in the supply chain are expected to lead to further cost reductions in the 2020-2030 period. Although in general more experience needs to be gained in order to allow for a quantification of the cost reduction potential reaching 2030, some qualitative trends can already be identified:

- In 2014, the average capacity of turbines in the EU was 3.7 MW (EWEA 2015). Trend towards larger turbines. Larger turbines offer higher reliability and energy capture as well as higher load factors, and lower operating costs. For example, load factors of German wind farms might increase from approximately 47% at present to as much as 55% by year 2050.
- Trend towards larger wind farm sizes. In 2014 the average size of connected European offshore wind projects was 368 MW. A higher wind farm size also contributes to economies of scale. Evidently, given this trend as well as clustering of wind farms makes that advances in farm design and wake control a technology issue of increasing importance.
- Integrated farm design, improved power forecasting and farm planning, active wake control.
- Trend towards increased preventive maintenance to minimize unplanned maintenance.
- Foundations: The *monopile* is currently dominating the market. However, several other designs exist**Error! Reference source not found.**. These are being tested and may lead to cost reductions or to the ability to unlock potential in deeper waters and diverse seabed conditions.
- Coordinated transmission planning. To date, improved coordination practices with better organization of tendering procedures are being implied at the national level with reduction of data gathering work on account of potential bidders. This is already leading to lower cost of energy. So far, the high potential benefits of coordination at regional level are still to be obtained.

Several innovation-related drivers of future deployment of offshore wind can be discerned. There will be an increasing scarcity of relatively near-shore sites in relatively shallow sea-beds, taking into account also public acceptance issues. Therefore, important technical and regulatory innovations are required to keep costs of further penetration of offshore wind in check. Technical innovations include:

- Technical innovations regarding foundations for deep water sites. For instance, for water depths exceeding 50 meters stable floating concepts need to be developed at low additional costs. Note that the North Sea area is almost everywhere within 50 meters deep.
- Technical innovations regarding integration of interconnectors with the connection of (hubs of) wind farms. Among others, HVDC circuit breaker technology needs to mature. The same goes for HVDC converter stations, converting the power injected from the wind farm AC grid to direct current for transmission by HVDC interconnectors.

In the case of wind offshore, the value per unit of energy generated very much depends on the generation time profile of a particular offshore wind farm. This profile has to be considered in relation to the evolution of the power price per trading time unit (e.g. 60 minutes, 30 minutes) on the power exchange in the zone relevant for the wind farm. The so-called profile factor with which the annual average power price needs to be multiplied is in the order of 1.2 in the case of onshore wind. This means that the annual average revenues per unit of onshore wind generated is on the order of (1/1.2) * 100 ≈ 83% of the annual average power price.

We do not avail of a reference of a typical parameter value for profile factor in the case of offshore wind. Presumably, this factor tends to be appreciably lower as currently under average North Sea conditions the load factor of offshore wind is on the order of 47%, i.e. much higher than is typically the case to date with onshore wind (some 26% in coastal Dutch and German North Sea coastal areas). Furthermore, balancing costs on the order of 2-5 €/MWh are associated with onshore wind. Also on this score, for offshore wind the additional discount to net unit value is less on account of the much higher load factor. Then there is the cost of back-up regulation and reserve power that has to be contracted by the TSO on account of wind generation. Again, these costs are lower for offshore wind as against onshore wind for the same reason. The high load factor of offshore wind enables operators of this technology to provide cost-effective ancillary services, such as downward balancing and voltage control (Rohrig, 2014).

-Distribution of grid-connection costs. This can be both a driver and a barrier, depending on the approach applied. In the case of wind offshore, key is who pays for the offshore connection from the offshore wind park to the onshore transmission network. Currently, two main approaches prevail –i.e. the German TSO model versus the UK OFTO model – with a mixture in some other Member States. In the German TSO model which tends to be followed by most littoral states of the (European) Northern Seas, the TSO is responsible for installing in an anticipatory way the offshore grid infrastructure up to (inclusive) the sub-stations near the (planned) German offshore wind farms and to operate it. The German competent TSOs are liable for the cost of idleness of offshore grid structures when planned wind farms are being realized with a backlog or planned wind farm investments are cancelled. This also applies to costs of curtailed generation because of network failures or late installment of the network infrastructure needed. These cost liabilities are socialized to German electricity consumers. Among others, Denmark has a roughly similar approach. The Netherlands will follow with in short after imminent regulatory changes. In Belgium, the TSO assumes part of the offshore connection costs. In contrast, in the UK developers of offshore wind parks have to assume the offshore connection costs themselves initially. Upon commissioning they divest their offshore grid assets to an Offshore Transmission Owner (OFTO) to be assigned by the UK national regulatory agency, OFGEM, through competitive bidding. The OFTO will recuperate his investment through transmission charges to the wind farm operator. Transmission charges of OFTOs are subjected to a TSO regulatory regime, supervised by OFGEM. Hereafter we will assume that the TSO model will prevail with socialization of offshore grid transmission network. In principle, this broadly puts offshore generators on a level playing field with their onshore competitors.

-Industrialisation and job creation. The UK provides an excellent example of the major economic opportunities that lie in the deployment of offshore wind energy. Whilst the earlier UK wind farms generally had relatively low UK content, one can see that this is rapidly changing. The offshore sector is now generating long-term

manufacturing, construction and service employment. In addition, the UK's position as the global leader in offshore wind means it is already attracting supply chain investment – such as the construction of major new port infrastructure and factories in Hull, and in several foundation, cable and vessel facilities – and creating UK jobs. (BVG, 2015).

3.1.2.2 Political drivers

Off-shore wind policy drivers have played a key role as suggested by the stakeholder interviews (see below).

3.1.2.3 Feedback – stakeholder interviews

Similar to the case for CSP, interviewees confirmed the relevance of the drivers presented in the report, however, highlighting that the key driver for the deployment of OWE is a political framework with clear and transparent policy ambitions/targets. One interviewee highlighted that (national) ambitions/targets for OWE can have an important trickle-down effect on key industry players with respect to their further commitment to enhancing innovative solutions as well as developing new solutions, be it for example turbine improvement, O&M strategies, and offshore cabling. Experience has shown that if the industry knows in advance government ambitions and support for OWE, manufacturers, they are more willing to commit to upgrading facilities in order to deliver necessary components for and equipment to install OWE farms. Two interviewees highlighted the recent improvements in the Netherlands, following the 2013 Energy Agreement between the Dutch government and stakeholders as an example of a good basis for driving the sector forward. As a follow up to the Energy Agreement, the situation has become more clear and transparent on what new OWE capacity should come into play in the coming years as well as more clarity on roles and responsibilities in achieving the OWE target. In addition, one interviewee highlighted that the industry is well aware of the fact that it needs to become competitive in the short-to-medium term, highlighting the example that the industry set its own target to reduce the cost of OWE to less than 100 €/MWh by 2020. One of the interviewees highlighted that an additional driver to offshore wind is the better wind conditions (more full load hours) and more available space at sea compared to land.

3.2 Potential barriers

3.2.1 CSP

In this section we will focus on those barriers which are deemed more relevant for CSP. Interviews will allow us to tell whether other important ones are missing.

3.2.1.1 Techno-economic barriers

-*Limited resource potentials in Europe*. CSP plants can be sited only in areas with adequate solar resources (ideally, with direct sunshine in excess of 1900 kWh per m2 per annum), which restricts its potential deployment in Europe to the Mediterranean area (Spain, Southern Italy, Southern France, Greece, Cyprus and Malta) (EurObserv'ER 2014). Direct normal irradiation can reach 2000 kWh/(m²a) in Southern Spain which is high compared to other EU countries, but low compared, e.g. to the 2500 kWh/(m²a) corresponding to the MENA region (Kost et al 2013). As a result, its highest growth potential is outside Europe, in the so-called Sun Belt region (between 40 degrees north and south of the equator). This region includes the Middle East, North Africa, South

Africa, India, the Southwest of the United States, Mexico, Peru, Chile, Western China, Australia, southern Europe and Turkey (IEA 2013)[9].

-*High costs*. Despite the aforementioned cost reductions in the past, cost of CSP plants is still high in comparison with conventional power plants and other renewable technologies (see section 2.2). Current investment cost for CSP plants have remained high in the range of 4,000-8,000 per kW, depending on the "solar multiple" – i.e. the ratio of the actual size of the solar field to the size that would deliver the rated capacity under the best conditions of the year (IEA 2014b). Local conditions, DNI, the presence of thermal storage and – last but not least – the maturity level of the project (i.e. pilot, demonstration or commercial) are crucial factors affecting those costs. Several factors affect the LCOE of CSP: location, technology, design and intended use (IEA 2014b)

The current levelised cost of electricity (LCOE) for PT plants ranges from USD 200/MWh (i.e. typically, plants with six hours of storage and high DNI) to USD 330/MWh (i.e. with no storage and low DNI). ST plants range from USD 170-240/MWh (i.e. with 12-15 hours of storage) to USD 220-280/MWh (with 6-7 hours of storage). Typically, investment and financing costs account for about 84% of the LCOE, the rest being operation and maintenance costs (IEA 2013).

-*Lower and uncertain cost reductions*. Cost reductions have been lower than initially expected. There was little change in the LCOE range for CSP projects between 2008 and 2012, although the range widened and grew somewhat with the burst in growth in 2012. Between 2012 and 2014, the LCOE of the projects in the IRENA Renewable Cost Database and other sources has trended downwards. The LCOE for recent parabolic trough plants without storage is in the range of USD 0.19/kWh to USD 0.38/kWh. Adding storage narrows this range to USD 0.20 to USD 0.36/kWh (IRENA 2015). Costs were expected to decrease as CSP deployment progressed, following a learning rate of 10%. This decrease has taken a long time to materialise. This anomaly can be explained by an increase in the cost of materials, particularly affecting the most mature parts of the plants, the power block and balance of plant (BOP). Other causes are the dominance of a single technology (trough plants with oil as heat transfer fluid) and a regulatory limit of a sub-optimal 50 MW of power output per plant in Spain, where most of the deployment occurred after 2006. The few larger plants that have been or are being built elsewhere are either the first of their kind in the world, with large development costs and technology risks (e.g., in the United States), or the first of their kind in the country, with large development costs and country risks (e.g., Morocco) or both (e.g., India) (IEA 2014b).

On the other hand, IRENA (2015) warns about the accuracy of predictions for cost reductions, especially for solar towers, given that most of the available operating experience and cost information refers to parabolic trough systems and that the early deployment of this technology makes it difficult to draw robust conclusions about what their cost structure may look like once their deployment accelerates.

-*Competition or complementarity with solar PV?* Direct competition from the other large category of solar technologies (solar PV) is frequently mentioned as a potential barrier for CSP in the future. Some authors even argue that this competition may be already delaying the deployment of CSP in some parts of the world. For example, IEA (2014b) notes that deployment in the United States was slow until 2013 because of long lead times and competition from cheap unconventional gas and from photovoltaic (PV) energy, whose costs decreased rapidly. The STE IEA Roadmap (IEA 2014b) shows that rapid deployment of PV has delayed the deployment of STE, although it is unlikely to impede it in the longer term.

9 The economics of the technology are even more dependent than PV on the quality of the resource for various reasons. First, the direct irradiance, which governs the output of a CSP plant, is more affected by clouds and atmospheric humidity than the global irradiance, which governs the output of non-concentrating PV, CSP technologies require large quantities (>5 kWh/m2/day) of direct normal irradiance(DNI) in order to function and be economic. This is in contrast to solar photovoltaic technologies, which can also operate on diffuse or scattered irradiance as well. Second, the thermal losses of a CSP plant's receiver and the parasitic consumption of the electric auxiliaries are essentially constant, regardless of the incoming solar flux (IEA 2014a, IRENA 2015).

Although competition between solar technologies might have led to low deployment of CSP, in the future they will complement each other and even reinforce each other, turning a case of technological competition into one of technological complementarity. The value of STE will increase further as PV is deployed in large amounts, which shaves mid-day peaks and creating or beefing up evening and early morning peaks. STE companies have begun marketing hybrid projects associating PV and STE to offer fully dispatchable power at lower costs to some customers (IEA 2014b).

3.2.1.2 Legal and administrative barriers

To our best knowledge, no study on the legal and administrative barriers specific to CSP is available, neither at the world nor EU level. According to IEA (2014b), difficulties in securing land, water and connections; permitting issues have been barriers encountered by developers to establish CSP plants. Permits for plants have been challenged in courts because of concerns about their effects on wildlife, biodiversity and water use. Some countries prohibit the large-scale use as HTF of synthetic oil or some molten salts, or both. In the EU, administrative barriers to RETs in general (i.e., not only CSP) have been a traditional concern of the European Commission for more than a decade.

There seems to be only anecdotal evidence that this has been a barrier in some specific cases and countries. Italy and the US have been mentioned as two specific countries where they might have been a problem. The Italian environment legislation does not allow for extensive use of oil in trough plants, however, limiting the technology options to more innovative designs, such as DSG or molten salts as HTF. Projects that would produce several gigawatts are still under consideration or development in the United States, although not all will succeed in obtaining the required permits, PPAs, connections, and financing (IEA 2014b). In Spain, this does not seem to have been a major barrier, according to our interviews (see below).

3.2.1.3 Political factors

It is well-known that the leading country in CSP (Spain) has retroactively cut its remuneration to this technology, which has led to virtually an absence of new projects in the pipeline in this country. The impact of the financial and economic crisis in other countries in the EU may also have had a detrimental effect in this sense, although the outlook in Italy and France is brighter than in Spain. Italy has put in place a specific FIT, which has survived the extinction of FITs for PV systems. France has a 540 MW CSP capacity target in its NREAP. Plants in the approval process or ready to start construction represent 20 MW in France and 115 MW in Italy, while other projects are under development (IEA 2014b).

3.2.1.4 Social acceptability/rejection

Social acceptability or rejection for RETs can be a main driver or barrier to their deployment. Social acceptability and rejection may be of a general nature (i.e., civil society is in favour or against the deployment of renewables or against deployment support) or it may have a local character (the so-called 'NIMBY' syndrome).

Likewise, social acceptability is related to the existence of real or perceived local benefits from given RETs for specific Member States (MSs) or regions. The local benefits of RES-E would be especially valuable in the case of countries depending to a large extent upon primary energy imports or those creating a local RES-E equipment industry. Indeed, the reduction of fossil fuel use (imports) has a positive effect upon a country's trade balance. In addition, RES-E deployment would be very attractive as a development alternative for rural regions, given the few available options in this regard apart from the traditional and declining agricultural activity. Finally, the local environmental impacts are also very relevant, leading to reductions in GHG emissions or air pollution in general (del Río et al 2012b).

To the best of our knowledge, no study on the social acceptability of CSP (neither in the EU nor elsewhere) is available.

Given the low penetration rate of this technology, and their location in arid, uninhabited, zones and without much ecological, touristic value NIMBY effects are unlikely to have been a barrier to this technology in the EU so far as confirmed in the interviews (see below). In the case of Spain, it does not seem to have been a barrier at all. In Spain, a group of 45 experts on CSP was created. They have identified and assessed potential barriers to CSP. Most of the members of this group argue social acceptability is not a challenge for CSP deployment in Spain (ALINNE 2015).

Three main local environmental impacts include land occupancy, water availability and impact on the landscape. CSP plants occupy more space than conventional power plants, although not more than non-solar renewable technologies. The electricity yield of solar technologies per unit of land is in the order of magnitude of wind or biomass (ESTELA 2014). Muller et al (2004) shows that in order to generate 1 MWh of solar electricity per year with CSP, a land area of only 4–12 m2 is required. This means, that 1 km2 of arid land can continuously and indefinitely generate as much electricity as any conventional 50 MW coal- or gas-fired power station. On the other hand, the most favourable areas for CSP are arid, and thus lack water for condenser cooling. Dry-cooling technologies for steam turbines are available and can be further improved, so water scarcity is not an insurmountable barrier, but an efficiency penalty and an additional cost. Wet-dry hybrid cooling can significantly improve performance with limited water consumption (IEA 2014b). According to ESTELA (2014), water needs are not greater than for conventional fossil or nuclear technologies and require less water per hectare (ha) than agricultural activities as this was assessed in the south of Spain so one can say that transforming agricultural land into STE application would not increase but reduce the water needs of such a region. It is true that water resources are often scarce in Sun Belt regions and there dry cooling towers can be used for cooling the condenser of the steam cycle.

Visual intrusion could be an issue. The tower in STE tower plants can be seen from far away. Parabolic trough plants are difficult to be perceived as visually disruptive on landscapes since the collectors are not high and spread over a large area (ESTELA 2014). Time will tell whether this could be a barrier with higher penetration rates.

The results of the interviews show that, by far the most relevant barrier is the high costs of the technology. All the interviewees believe that the cost of CSP plants is still high in comparison with conventional power plants and other renewable energy technologies. This is closely followed by a policy barrier: uncertain and retroactive policies, particularly in the case of the leading CSP country (Spain). Limited resource potentials in Europe and access to credit come as the third and fourth main barriers, respectively. Regarding the least relevant barriers, social acceptability is not relevant at all for 5 out of the six interviewees. This is by far the least relevant barrier, followed by legal and administrative barriers and competition with solar PV. However, the lower cost of solar PV was mentioned as a relevant barrier in the future by several interviewees.

3.2.2 Offshore wind

3.2.2.1 Techno-economic barriers

-*High costs*. Relatively high costs can also be considered to be a barrier for offshore wind. At present, the cost of energy for offshore wind is relatively high. Reimers and Kaltschmitt (2014) provide projected cost for three notional German “reference wind farms”, based on a literature study. The assumed distinct assumptions are shown in Table 7. The three reference farms are estimated to cost 2273 €/kW (farm A), 2507 €/kW (B) and 2757 €/kW (C) respectively of which network costs (internal cables; other costs socialised) represent 89 €/kW, 90 €/kW and 91 €/kW respectively. When under another national regulatory regime the wind farm developer is responsible for connection to the shore, network costs may well rise up to 500€/kW. Reimers and Katschmitt (2014) project on cost data as per year 2013 levelised cost of energy of 11.0-13.1 €ct/kWh.

Sometimes market information can be obtained from the actual winning bids of tenders. The Dutch Gemini project was awarded in a tendering procedure at a total bid price of 17 €ct/kWh including network connection to the Dutch shore[10]. The financial close of this 600 MW project (150 * 4MW turbines) project at a total project cost of €2.8 billion (≈ 4667€/kW) was on 14 May 2014; whilst the tender occurs in year 2011. The distance from shore is 85 km and the water depth 28-36m. Foundation will be done with monopoles. Planned annual production will be 2,6TWh/a, i.e. with a load factor of approximately 49%. In stark contrast to the high cost of Gemini stand the cost of the winning bid for the 400 MW Danish Horn Rev 3 project at 77 ore/kWh (10.3 €ct/kWh), as announced on 16 March 2015. This is a project in shallow waters at 20 km from shore with the Danish TSO assuming the offshore interconnection costs and compensation responsibility for network contingencies. We may tentatively conclude that the Dutch Gemini project is at a relatively high-cost site, was tendered when the financial crisis was still in full swing, and at cost-raising general conditions such as responsibility of the bidder for network interconnection with the Dutch onshore transmission network. *As per 2015, with responsibility for interconnection offshore for the competent TSO typical cost of energy for a European offshore wind farm will, contingent notably on siting (i.a.: water depth, distance from shore/harbor), be in the range of 10-15€ct/kWh.*

Table 7: Breakdown of estimated current cost of three German notional reference offshore wind farms.

	A	B	C
Distance from shore	10	60	120
Distance from harbor	20	90	150
Water depth (m)	10	25	40
Wind regime (m/s)	9.5	10	10.5
Foundation	Monopile	Jacket/Tripod	
Wind turbine	Asynchronic generator		

Source: Reimers and Kaltschmitt (2014)

3.2.2.2 Legal and administrative barriers

Concerning offshore wind, permitting procedures can be cumbersome for offshore developers, as the responsibility for granting permits is typically scattered through several governmental agencies. This can lead to delays and creating additional uncertainty for investors.

3.2.2.3 Political barriers

The issue of retroactive cuts in remuneration as experienced by onshore wind developers as well as PV developers e.g. in Spain has not been an issue for offshore wind developers. However, constant changes in the design features of support schemes remain a concern and can create unnecessary barriers for offshore wind deployment. For example, the design of the tendering model in the German Renewable Energy Sources Act 2016 is crucial for the future of offshore wind energy. "The offshore wind industry will already need clarification of the tendering design in 2016 so that expansion can be continually moved forward. To avoid a stop and go situation in the market, it is also imperative to create clear rules for the transition from fixed rate remuneration to a competitive tendering process for every model[11].The transition to tendering is regarded as potentially endangering security of investment. Furthermore, lack of RES targets at national level for Member States is creating uncertainty in the market.

[10] http://geminiwindpark.nl/feiten-en-cijfers/

[11] https://www.wind-energie.de/en/press/press-releases/2015/offshore-wind-energy-half-year-figures-2015-germany-expansion-schedule

3.2.2.4 Feedback – stakeholder interviews

Interviewees generally agreed that the lack of post 2020 defined ambitions for offshore wind by national governments is a key barrier. One interviewee highlighted that governments need to take more responsibility in translating a CO2 emissions reductions into RES ambitions, especially since national binding RES targets will be replaced by an EU-wide RES target in light of the forthcoming decade (i.e. 2020-2030). Furthermore, in some countries there is conceivably lowered OWE ambitions resulting in less momentum for OWE deployment, therefore constant tendering procedures are needed to keep the momentum in OWE deployment. Several interviewees highlighted the grid infrastructure constraints and sufficient funding available for investing in new infrastructure as additional key barriers. The example of Germany was highlighted, where short-to-medium ambitions have been downsized, largely due to foreseen grid infrastructure constraints. One interviewee highlighted that an important barrier not mentioned in this report is the Europeanisation or regionalization of the OWE deployment. National markets for OWE have been developing in their own way. Each country has different approaches to regulations, support and practices. Lack of coordination and alignment of planning, regulatory issues, support schemes, etc. across borders is an important barrier. Finally, one interviewee mentioned that an important barrier is the fact that there is still a small supply chain, i.e. too few manufacturers delivering required components/services. Furthermore, it was mentioned that costs have been rapidly decreasing in recent years, however, there is a risk that the sector becomes too optimistic with regard to further cost reductions. Low interest rate and low steel prices have contributed to lowering the LCOE. However, low interest rates and steel prices could rapidly change, these price risks need to be better anticipated.

4 Policy combinations to encourage the uptake of SMTs

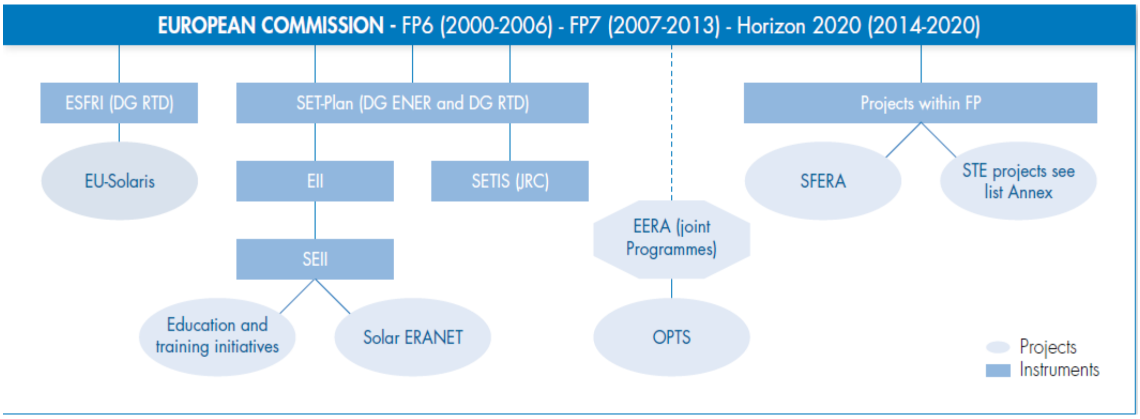
The previous section has shown that, as a less mature technology, which is in the early deployment stage, CSP and wind off-shore have had significant potential for improvement. In general, improvements in the technology would lead to cost reductions or higher revenues. These improvements could come as a result of RD&D or through learning effects during diffusion. In addition, the increasing adoption of a technology leads to cost reductions as a result of dynamic economies of scale. Therefore, combining support for RD&D and support for deployment is clearly justified for technologies at this stage.

An initial decision is how to balance support for R&D and for deployment in order to avoid the problems experienced in the past with solar PV, where there was a clear imbalance: too much deployment support instead of R&D (Albrecht et al 2015). Public support at the commercialization stage is inherently greater than for previous stages of the innovation process (IEA 2012). Note that cost reductions are, thus, endogenous to diffusion. Both interact. And cost reductions are a result of both deployment and RD&D. Therefore, both types of measures are inherently interrelated. A sine-qua-non condition to facilitate diffusion of the technology is to reduce its costs. In turn, this will allow further cost reductions.

Regarding R&D support, section 3 has shown that there is a large potential for innovation and many possible paths to improve CSP technologies. The most appropriate instrument for providing RD&D support should be implemented at both the MS and EU levels. Broadly, this could be in the form of direct RD&D support for public institutions specialised in CSP and/or in materials and components which are required for CSP. Or it could lead to support for RD&D in industry though fiscal incentives or other instruments. An optimal path is to combine both, leaving public RD&D for the initial stages of the RD&D process, where the existence of a market failure is more likely (see del Río 2010) and support for private RD&D for the commercial applications since firms are closer to the market and are aware of and can respond better to market needs. While support can be provided by national institutions, coordination of this support across MS together with the reinforcement of EU funded programs is advisable. Which instruments seem better fit for the job will be explored in the interviews to relevant stakeholders.

Currently, R&D support at the EU level for CSP is provided by Horizon 2020, the biggest EU research and innovation program ever, with nearly €80 billion of funding available over seven years up to 2020. However, no data on how much of this funding is going and will go to CSP are available. The European Solar Thermal Electricity Association (ESTELA) believes that, with a strong focus on technological demonstration projects, this framework is of great importance for the STE sector and a main driver to reach the objectives described in the STE Solar Industrial Initiative: to reduce cost, increase efficiency and improve dispatchability and environment profile (ESTELA 2012). In the past, European entities have funded important projects (figure 13).

Figure 13: Overview of the European schemes for STE funding



Source: ESTELA (2012). See Annex II for a complete description of these schemes.

Another instrument which has not been successful, according to the European industry association, is the NER-300, which has funded 5 CSP projects in Greece, Spain, Italy and Cyprus (Crespo 2014).

However, ESTELA claims that there is a ratio of 80:20 in terms of what they put in from their own funds compared to national and European research programmes (CSP today 2014). In addition, there are other national and regional financing programmes. National programmes supporting CSP exist in Cyprus, France, Germany, Greece, Israel, Italy, Portugal and Spain. Andalusia in Spain, Languedoc Roussillon in France and Nordrhein-Westfalen in Germany have regional public funding schemes. However, European funds have only had limited usefulness, according to ESTELA. They helped to catalyse early projects such as Gemasolar, Andasol 1 and PS10, but the European Investment Bank has been the single biggest contributor. According to Estela's president (Luis Crespo): "Our sector is one that requires support at the commercial level, through things like project finance and soft loans, not at the laboratory level. That is not happening. Support schemes are not aimed at a commercial level" (CSP Today 2014). This approach contrasts sharply with the situation in the US, where the government is pouring cash into commercial-scale CSP R&D through the Department of Energy's SunShot initiative (op.cit.). ALINNE (2015) argues that support in the form of innovative demonstration plants within a public-private collaborative framework and funding of R&D projects with the participation of companies and (public) research centers have proven successful in the Spanish context and recommends their continuation in the future.

In the case of wind offshore, support for emerging offshore wind technologies through RD&D funding and grants would also help to accelerate wind offshore development. Novel technological solutions to turbine foundations, HVDC circuit breaker technology and HVDC converter stations warrant RD&D funding to match project finance by private consortia to implement demo projects. Demo projects should be implemented the sooner the better. The proof of the pudding is in the eating: physical demo projects will have to encourage investors to make more realistic risk projections and to pull them over the threshold of a final investment decision with some further persuasion of giving such projects. Projects of Common Interest (PCIs) status with a subsidy component attached to it as well as participation of public development finance institutions such as EIB and KfW. Another key area of attention is innovation in O&M and supply chain management. An important determining factor for strong private consortia to invest e.g. in specialized installation and maintenance vessels is confidence in a reliable, predictable, long-term support framework. Moreover, appropriate technology research institutes can play quite a supportive role in accelerating innovation in technological applications.

Regarding deployment support, which are the main elements (framework conditions and specific instruments)? Which criteria or requirements should these elements comply with? Instruments should be effective (lead to an increase in installed capacity), cost-efficient (leading to the lowest system costs, including low capital and financing costs and greater market exposure), dynamically efficient (provide a continuous incentive for innovation), equitable, socially acceptable and politically feasible (by avoiding excessive remuneration and high total policy costs).

Framework conditions refer to those aspects for RES-E support that are either outside the support system itself or on aspects that may be designed similarly irrespective of the type of system applied (Bergmann et al 2008 p.133, see also del Río et al 2012a). The former include grid access procedures, permit procedures, the existence of long term, binding targets or investment security. This later condition is critical for very capital-intensive technologies, for which most investments are made up-front, financial costs play a very relevant role in their cost structure and these costs are obviously negatively affected by higher policy-induced investors' risks.

Therefore, an obvious first policy recommendation is to provide as stable and credible support as possible. In turn, this entails setting long-term targets, ensuring predictable changes in the remuneration for new plants and avoiding retroactive changes for existing plants. Governments' commitment to long term wind-offshore and CSP support is vital to create a stable climate for investment. A predictable (long-term) policy framework is an essential prerequisite to attract large investments. Otherwise, the risk premium for investments substantially increases and financing costs rise (see Rathmann et al 2011). This may lead to higher remuneration levels, greater policy costs and consumers paying more in their bills (if the policy is financed through electricity bills). Therefore, appropriately designed public policies may contribute to reduce these costs. Regulatory uncertainties and retroactive policy measurement should be avoided in order to minimize perceived risk and lower the (perceived) WACC. Technology-specific deployment targets with near-term milestones are being proved effective in stimulating renewables deployment. Such targets should be set voluntarily at national level, given the fact that no mandatory national targets apply for the 2020-2030 decade. In the long term governmental efforts are also needed in the assessment of the broader environmental implications of large offshore wind deployment, e.g. impact on sea life and on birds migration. A better understanding in this area will enable the rollout of informative campaigns to ensure responsible development and greater social acceptance.

Obviously, apart from the framework conditions, the type of instrument implemented may make a difference in terms of successful deployment, defined as that which complies with most of the aforementioned criteria. In this context, a major concern of policy makers in the EU nowadays, as suggested in the State Aid Guidelines, is to avoid very high policy costs and increasing the market exposure of RES. We consider six main instruments which we deem potentially relevant to support CSP in the EU: feed-in tariffs, feed-in premiums, quotas with tradable green certificates (TGCs), auctions, investment subsidies and soft loans. The following table provides a synthesis of their pros and cons to support CSP in the EU.

The table shows that, while relevant to reduce the financing costs, some instruments are unlikely to be sufficient to promote a large-scale deployment of CSP. These are soft loans and investment subsidies. In the United States, the loan guarantee programme of the DoE has played a key role in overcoming financing difficulties and facilitating technological innovation (IEA 2014b). In Spain, soft loans were awarded in the initial stages of RES-E deployment and the instrument was quite successful in this context (Interview energy expert). Therefore, these instruments will likely complement the other four. Policy combinations in this context may lead to a more successful CSP deployment.

Table 8: Advantages and disadvantages of different instruments for the promotion of CSP in the EU.

	ADVANTAGES	DISADVANTAGES
FITs	Lower risks for investors. Effectiveness	Total support costs (in the absence of caps). Less market-compatible, not in line with the EU Guidelines.
FIPs	More market-compatible than FITs. Effectiveness	Fixed FIP: Higher investors risks than under FITs, but less than TGCs (Rathmann et al 2011). Risks can be further reduced under sliding premiums.
Quotas with TGCs	The most market-compatible	High risks for investors. Possibly low deployment of less mature technologies, especially in the absence of banding. Higher support costs, especially in the absence of banding.
Auctions	Market-compatible. Low risks for investors after bidding procedure.	Effectiveness unproven (risks of underbidding). If technology-specific auctions: possible market power (excessive support). If technology-neutral auctions: possibly low effectiveness. Very limited international experience in supporting CSP.
Investment subsidies	Quite appropriate for capital-intensive technologies (mitigating financial costs).	It does not provide incentives for the efficient operation of the plant. Unlikely to be sufficient to trigger significant deployment (complementary instrument).
Soft loans	Quite appropriate for capital-intensive technologies (mitigating financial costs).	Unlikely to be sufficient to trigger significant deployment (complementary instrument)

Source: Own elaboration.

Some of those support schemes have already been applied in the EU to support CSP and wind off-shore.

The countries with CSP plants in operation, under construction or which are expected to have CSP plants installed in 2020 according to the NREAPS have the following support schemes (Estela 2012, EurObserv'ER 2014, RES LEGAL 2015):

- **Spain**: FIT. In June 2013, Spain introduced an entirely new subsidy system capping the earnings of all existing renewable power plants. The FIT and market price plus premium systems have effectively been abolished retroactively and replaced by a sum to be allocated based on the plant's installed capacity to compensate for investment-related financial outlay. Under the decree, generators will earn a rate of return of about 7.5 percent over their lifetimes. This rate, which may be revised every three years, is based on the average interest of a 10-year sovereign bond plus 3 percentage points.
- **France**: Solar tenders (FIT set in a tender).
- **Italy**: FIP. The incentives, calculated by the government, are in addition to the revenues from the sale of electricity generated and fed into the national grid. The FIP will be reduced by 5% for the power plants connected to the grid in 2016 and by 10% for those connected in 2017.The incentives will be paid for 25 years.
- **Germany:** Sliding premium for >100 kW and FIT for <100kW.
- **Greece:** FIT (with capacity caps) + capital grants.
- **Portugal:** FIT (suspended).
- **Cyprus:** FIT + auction. CSP. 25MW licensed for the period 2009-2013 (25MW), 50MW auctioned in 2013-2014.

The choice for one or another instrument depends on the priorities of governments. In general, if jump-starting the market or large-scale deployment is the aim, then FITs have proven a more appropriate instrument. This has been the case for other RETs (i.e., wind on-shore and solar PV) in the EU. Therefore, support mechanisms such as FIT and FIP will still be indispensable instruments to enable CSP and large offshore wind deployment reaching 2030.If properly designed, FITs are the most straightforward way to provide investors with the security necessary to overcome otherwise prohibitive development risks and ensure adequate financial returns. An alternative would be to combine the FIT with a properly designed reverse auction scheme. Under this combination, remuneration levels would be set in the bidding process, instead of being administratively set. Once the contracts are signed, they would mostly work as a FIT. Experience with quotas with TGCs have shown that they can lead to excessive unitary remuneration (€/MWh) (Steinhilber et al 2011). However, it has also been shown that they can contain overall costs (€, the result of capacity times unit remuneration) better than FITs (although this can be mitigated by combining the FIT with a capacity cap, see below).

Quite some regulatory innovations are warranted to get integrated wind offshore grid projects off the ground such as:

- Voluntary support convergence or rather harmonization, applying either the Joint Projects between Member States or the Joint Support Scheme cooperation mechanism, applied to joint offshore wind projects.
- New common (or coordinated) regulation is needed between cooperating Member States regarding integrated grid projects enabling transfer of offshore wind electricity to the other Member State(s) connected by the integrated grid structure concerned without the offshore wind farm operator having to relinquish support benefits he would have received through direct transfer of power generated by his wind farm to the national shore instead of exporting it.
- When the power concerned is physically being exported, then it should be determined in which bidding zone the wind farm operator should bid.
- Non-support cost and network operating rules (network codes) should be converging or rather be harmonized to the maximum extent possible. For example, technical requirements regarding Voltage Ride Through should be streamlined.
- The strategic planning of sites for and sizes of future offshore wind parks between cooperating Member States should be coordinated and permitting procedures should be harmonized.

Regulatory innovations to endorse integrated offshore grid structures, notably but not only when they are connecting more than one power market zones would be useful.
The advantages and disadvantages of specific instruments are mediated by the specific design elements of each instrument. The discussion below illustrates the relevance of some possible choices which can be made in this context.

Design elements may mitigate some of the drawbacks traditionally attached to specific instruments, although they may bring other problems. For example, caps (capacity, generation, budget) would mitigate the policy risks of an explosion of support costs under FITs (which has been the case for other solar technologies in the past), although they would increase investment risks in an otherwise low-risk instrument. Sliding premiums could reduce the risks for investors under FIPs (compared to fixed FIPs). Cap-and-floor remuneration levels under FIPs would limit both policy costs (caps) and investor risks (floors). Maximum and minimum TGC prices would have a similar impact (see Annex 1 for some examples of design elements currently applied to support CSP).

In addition to deployment support, other instruments are likely to be relevant. In particular, a main success factor for CSP deployment and CSP deployment support is the social acceptability of this support. In this context, there is usually an excessive emphasis on the support costs whereas the other side of the economic equation (the local socioeconomic and environmental benefits) are less stressed. While controlling the total support costs is important to avoid a social backlash against the policy, it is also important for the political economy of CSP support to *inform the public* about the benefits (already existing or potential) of the implementation of this technology during the whole innovation process, including employment and industry creation, export opportunities and reduction of energy imports.

Finally, *legal and administrative barriers* (leading to long lead times for deployment and additional costs for project developers) are usually mentioned as a barrier to the deployment of RETs in the EU. Several EU documents attest so (see del Río and Peñasco 2014). While the previous sections have shown that there is no evidence that they might also be a main barrier to CSP (beyond other RETs), we can still assume that they will be a barrier which has to be removed. Thus, a mitigation of those barriers is needed by implementing clear and streamlined authorization procedures across the EU.

Given the relevance of permitting procedures as a barrier for wind offshore developers, standardised, streamlined permitting procedures are therefore essential to enable large scale deployment in the 2020-2030 decade. Successful examples of one-stop-shops for permits have already been reported (for example such a one-stop-shop was set up by the UK government for its Round 2 offshore tendering process).

Key issues to be addressed for accelerating offshore wind development in notably the Northern and Baltic Seas include coordination of offshore development in maritime spatial planning. So far, an *ad hoc* approach tends to be applied by littoral Member States in an uncoordinated way with emphasis on harvesting the low hanging fruits, i.e. as much as possible near–shore wind farms in shallow sea areas. Low priority is put on removing bottlenecks for exploiting sites further away from shore at reduced costs. Reducing technological and regulatory barriers, sketched above, result in shorter lead times. However, from a strategic point of view much higher priority needs to be attached to tackle such barriers.

A main aspect regarding wind offshore deployment is regional coordination. In other to enable the developments and maintain the trends outlined in the previous section in the period 2020-2030, appropriate policy measures should be in place. From a societal point of view, the overall offshore wind power and network development needs to be coordinated in a cost-effective fashion. As long as offshore wind farms can be developed near-shore in shallow seas, the prevailing national approach does not raise costs very much. Under this approach the main cost raising factor is the difficulty to agree on common offshore transmission technology standards. Yet in the not distanced future cheap offshore wind farm sites will become more and more in short supply. Scarcity of relatively near-shore sites in relatively shallow sea-beds will become higher, and public acceptance issues will become a greater concern. Hence, a strong case can be made for at least regional coordination among Member States with littoral coasts (see e.g. Meeus, 2014; NSCOGI, 2014, Jansen et al, 2015).

Therefore, regulatory innovation regarding coordinated planning, implementation and supervision of offshore wind farms at (sub-)regional level by littoral Member States, notably in the Northern Seas is required. The continuation of purely national regulatory arrangements increases the transaction costs and gives rise to policy and regulatory uncertainty for project developers and technology providers alike. Consequently, it negatively affects both the deployment rate and the rate of technological innovation. For near-shore sites at low water depths, appropriate national approaches to promote offshore wind will suffice to roll out offshore wind. However, for cost-effective further penetration of offshore wind, regional coordination is required. Such coordination will be even more important with the development of complex or hybrid offshore solutions, i.e. where one or more offshore wind parks are directly connected to interconnectors. In such cases, electricity from wind parks can be transported to more than one country. Therefore, agreement of how to allocate the costs (e.g. connection of the wind park to the grid) and benefits (e.g. the green value of the electricity generated by the wind parks) between involved countries will have to be reached, as well as agreement on how to address the regulatory challenges. As for the time being, a top-down approach is not likely to be accepted, the best chances seem to be for a bottom-up coordinated approaches by like-minded littoral states with closely integrated electricity markets and similar support schemes. When such approaches prove effective, this may pave the way for acceptance among littoral Member States of more top-down oriented coordination.

In particular, the following key areas can be identified for coordination:

- Aligning grid codes regarding technical regulatory issues
- Aligning cross-border intra-day and balancing markets
- Streamlining permitting procedures
- Introducing joint support schemes for offshore wind with proper allocation arrangements of support cost and benefit allocation

- Further involvement of national and multilateral public financing agencies to signal good risk understanding and less risk uncertainty to other financing partners.

Therefore, the above suggests that several elements are needed to tackle the barriers to CSP and wind offshore in the EU and activate its drivers.

The interviews confirm the relevance of having different policy elements to ensure the uptake of CSP in the EU, i.e. a policy mix. The relevance of two different types of components is stressed: framework conditions and instruments. First, framework conditions are considered as the most relevant policy to trigger CSP deployment in the short, medium and long terms. These include long-term targets, predictable changes in the remuneration for new plants and retroactive changes for existing plants. In this case, the interviewees emphasize the importance of regulatory stability.

Regarding the instruments, the interviews confirm the relevance of both types of support being considered: deployment and innovation support, just behind the importance attached to the framework conditions. Among the innovation instruments, one stands out: innovative demonstration plants. The other two are less relevant (support for RD&D in industry through, for example, fiscal incentives and support to public research centers through direct RD&D support). The importance of demonstration projects as a way to improve the quality of the technology and reduce their costs through learning effects is emphasized by all the company stakeholders (investors).

A high relevance is also attached to deployment support. FITs (whether set administratively or though auctions) are the preferred instrument, followed by FIPs. Within FITs and FIPs, the stakeholders do not have a clear preference for having the remuneration set through auctions or administratively. Quotas with TGCs are regarded as the least relevant of all deployment instruments. This is probably related to the fact that these have not been used (at least in the EU) to promote CSP and that they are generally regarded as not suitable to promote the still maturing technologies in the literature. Our results confirm this belief. The so-called “secondary” instruments (soft loans and investment subsidies) have an intermediate degree of relevance. This is also the case with education and information instruments and the removal of administrative barriers.

For OWE, the interviewees confirmed that there is a need for more alignment and coordination of national policies and provisions, mentioning that progress in this direction is among others being sought under the 2016 EU Dutch Presidency period. The interviewees also highlighted the role of the EU and EU funds in addressing barriers to OWE. Firstly, there is a need to boost EU funds geared to (cross-border) grid infrastructure developments needed to facilitate OWE deployment. Associated with that, EU R&D programs should be boosted to provide more funding for innovation of various technology components, e.g. DC breakers, turbines and foundations. On the other hand, two interviewees highlighted the tedious application procedures for acquiring EU-funds for R&D activities within the e.g. H2020 framework, with accompanying low success rate. The EU should address this factor in the forthcoming MFF. One of the interviewees also highlighted the role EU could play providing a platform for marine data and modeling exchange. Whilst one interviewee highlighted the need for improved marine spatial planning in light of foreseen increased OWE deployment, another interviewee felt that this was sufficiently addressed and immediate improvements in this area is not needed. On the other hand, improved regulatory framework for grid infrastructure is certainly needed.

5 Conclusions

- Drivers and barriers for RES (-E) technology deployment partly depend on the position of the respective technology in the technology diffusion curve. In addition, there are some technological particularities which affect the degree of diffusion of a specific technology which should be taken into account when proposing policy measures aimed at encouraging the deployment of the two SMTs considered in this report (CSP and wind off-shore).
- The literature suggests that significant technology improvements and cost reductions can be expected as both CSP and offshore wind industries scale up. However, CSP and offshore wind are at different maturity levels. Furthermore, there are also different maturity levels within e.g. the range of CSP technologies.
- Cost reductions for both CSP and offshore wind are a result of several factors, including economies of scale, learning effects at both industrial and plant level, and increased plant/park size.
- Offshore wind has experienced a larger cost reduction compared to CSP from 2000 until today, largely due to the fact that the annual and cumulative deployment rate has been significantly higher for offshore wind compared to that of CSP in the period.
- Trends towards larger turbines, larger wind farm sizes, integrated farm design, improved power forecasting and farm planning, active wake control, improved foundations, and coordinated planning will positively impact on the cost. For CSP, cost reductions will be due to several factors, including economies of scale, learning effects at both the industrial and plant level, increased size and technological improvements due to innovation. The first two are the result of deployment, whereas innovation is both the result of RD&D and, to a lesser extent, deployment. A large potential for innovation exists in CSP. In general, key technoeconomic drivers for the take-off of CSP are its high technological dynamism and competition between different designs, its potential for cost reductions, the possibility for hybridization, its higher value compared to other RETs and industry consolidation.
- For both technologies, political drivers play a key role; these include targets (RES deployment and GHG emission reduction) in efforts to primarily combat climate change and energy security threats, and supporting policies, such as financial support (FiT, FiP and tradeable green certificate schemes to promote RES). Key barriers to further CSP and offshore wind energy deployment include high costs relative to other (non-RES based) technologies generating electricity as well as cumbersome permitting procedures. For CSP, specifically, key barriers include limited resource potentials in the EU (in particular in Northern EU), high costs, uncertain cost reductions, and retroactive cuts in remuneration, which has led to greater investor uncertainty.
- For offshore wind, specifically, key barriers include high costs and grid connection challenges.
- However, new challenges (barriers) also evolve as RES market share growth rates accumulate. For example, offshore wind players are experiencing increasing competition with other activities at sea, such as fisheries, shipping, dredging and sand extraction, for ideal locations for setting up offshore wind parks. Also, as RES penetration grows, wholesale electricity prices are reduced, which negatively affects the profitability of RETs (as well as other technologies) under market-based support schemes (notably, fixed FIPs).
- In order to increase the deployment rate of both technologies, an obvious first policy recommendation is to provide as stable and credible support as possible. In turn, this entails setting long-term targets, ensuring predictable changes in the remuneration for new plants and avoiding retroactive changes for existing plants. Appropriate and well-designed remuneration schemes are necessary. Given the high capital costs of both technologies, FITs seem to be an appropriate instrument in this context. Furthermore, given the relevance of permitting procedures as a barrier for wind offshore developers, standardised, stream-lined permitting procedures are therefore essential to enable large scale deployment in the 2020-2030 decade. Successful examples of one-stop-shops for permits have already been reported (for example such a one-stop-shop was set up by the UK government for its Round 2 offshore tendering process).

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ANNEX 1. DESIGN ELEMENTS IN SUPPORT SCHEMES FOR CSP.

Regarding the specific design elements applied in current policy practice to support CSP in the EU, some examples are worth mentioning.

Italy applies a stepped FIT for CSP, with banding according to size (total receiver surface) and the solar fraction. The FIT system in place since 21/12/2012, involves banding by total receiver surface, around the 2500 m2 threshold and the amount of electricity from non-solar sources required to integrate the solar output. The FIT for large plants (>2500 m2) is €0.32/kWh where the solar fraction is over 85%, €0.30/kWh from 50 to 85%, and €0.27/kWh where is it less than 50%. The FIT will be paid from 25 years and drop by 5% from 2016 onwards and by a further 5% from 2017 onwards. The FIT for small plants (<2500 m2) adopt the same solar fraction rules and are €0.36/kWh, €0.32/kWh and €0.30/kWh respectively and apply the same sliding scale rules. Plants with more than 10000 m2 of receivers will be required to have an energy storage system (RES LEGAL 2015, EurObserv'ER 2014). The Feed-in Tariff will be paid for 25 years and drop by 5% from 2016 onwards and by a further 5% from 2017 onwards. This stepped FIT provides a greater incentive for smaller plants, i.e., it encourages smaller-size plants vs. larger ones. This has its pros and its cons. It has been mentioned in a previous section that one of the main factors to reduce the costs of CSP is increasing CSP plant sizes. Obviously, this stepped FIT would go against upsizing. But, on the other hand, it would lead to a more dispersed deployment of CSP in the territory, possibly circumventing the NIMBY problem.

In addition, the Italian FIT promotes hybridization, which, as mentioned in section 3, is a driver to greater CSP penetration. A main problem when supporting hybridization is that the solar fraction is not taken into account and full support is given to plants with a very tiny fraction of the electricity produced coming from solar. This is circumvented by the Italian FIT, although it could be argued that the shares leading to different remuneration levels are somehow arbitrary.

Since April 2014, Greece introduced FIT reductions for all RES for new and operating projects (~25% w.a.), enforced a discount from RES producers' 2013 remuneration (10-37.5%), set capacity caps for FIT eligible installations of PV, CSP, biomass and biogas and removed the annual inflation adjustment of FITs (CEER 2015). Greece provides a FiT of 26.5 c€/kWh, which rises to 28.5 c€/kWh if at least 2 hours of storage is incorporated.

Outside the EU, an interesting design element for a remunerating CSP is the one implemented in South Africa, with hourly discrimination (time-of-day tariff +270%) (Crespo 2014). This would take into account and help to support the "system value" of CSP, since a greater support level would be provided when the CSP plant produces electricity when it is most valuable (i.e., at peak times).