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Topic 5

Offshore Grids: Towards a Least Regret EU Policy

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Executive Summary

Context and rationale of the report

The existing transmission grid in Europe is located mainly onshore. Nonetheless, there are also grid developments offshore that should not be neglected. Indeed, there is also part of the transmission grid located offshore, which includes both the connection of distinct onshore grids and the connection between offshore generation sites and onshore transmission grids.

Considering the EU climate and energy policy objectives as binding, the grid will continue its development offshore through the following decades to enable the achievement of the objectives regarding the EU electricity generation mix. Indeed, a significant increase of offshore wind power capacity is expected in several member states (including Germany, France, the Netherlands and the UK) and, consequently, also an increase in electricity grid located into the sea. Furthermore, the intended share increase in renewable energy technologies in the overall generation mix will lead to an increase in the variability and intermittency of electricity production. This variability can be tempered with a stronger transmission grid, since the latter would allow for the unrestricted transfer of electricity between the supply and demand sites, even when very distant from each other. Thus, it means that, besides the capacity increase in the existing lines, it will also be necessary to invest in new lines; and part of this transmission will inevitably be offshore.

Thus, grids are already developing offshore, and this development will continue even though at what pace and how they will develop is still uncertain. Indeed, there are different possible configurations for a future offshore grid: it can be a simple multiplication of standalone lines that provide each a single service

(either connection of generation, or connection between transmission grids); or it can be a more integrated infrastructure like an offshore meshed grid that combines and interconnects dozens of offshore lines and generation units (hereafter combined solution). A combined solution can usually bring some advantages compared to the multiplication of individual lines. Indeed, it typically requires fewer physical components, but has higher power capacity, which is commonly beneficial due to the economies of scale present in transmission systems. This has also been the case onshore with the development of the transmission grid, where a combined solution approach has been favored for a long time now, especially since the introduction of both technology and operational standards in the previous century.

However, the development of a combined solution offshore is still unpredictable due to the existing uncertainties regarding necessary technological developments. In fact, most developments offshore use a less-known technological system for which standards do not yet exist, i.e. it is based on Direct Current (DC) instead of Alternating Current (AC) systems; and an integrated solution offshore would require some technology components that are still not available today. Moreover, there are also strong costs uncertainties, not only due to the referenced uncertainties in technology development, but also due to the unclear role of a future offshore grid. Indeed, there are different visions on the possible role of an offshore grid in the future; while some envisioned a regional grid whose main role is to integrate offshore wind from Northern Europe, others envisioned an infrastructure which is integrated into a more global grid (covering EU and neighboring countries).

The aim of our report is to formulate policy recommendations to the European Commission (DG Energy) on offshore grids and their future development.

In order to do so, we kept in mind the existing uncertainties regarding future offshore grid developments but, at the same time, we considered the role of regulation and the importance of its proactive character.

Main findings and recommendations

Standalone lines

From our analysis of common regulatory practices as well as specific case-studies of regulatory procedures in different member states, it is clear that the frames that are applied to the investment in standalone lines are not economically sound, i.e. they are not aligned with the three guiding principles of an economically sound frame (i.e. planning, competition, and beneficiaries pay). Nonetheless, there are already some pioneering member states (e.g. the UK) that are beginning to follow a better economic approach.

In the case of standalone lines, there is no need for a specific EU intervention because the possible negative economic effects are mainly local, and for the issues that do require an EU intervention, we consider that the same intervention should be applied to standalone lines as to onshore transmission investments. Still, it is important to continue the policy actions that are ongoing for grids, onshore as well as offshore.

At the EU level, there are important policy actions in place: the implementation of the third package is indeed ongoing, and an infrastructure package has recently been proposed by the European Commission. At national level, it is also important to continue the experimentation with novel regulatory frames (e.g. Germany, UK and Sweden) that have been fine-tuned for the connection of offshore wind farms. Note that the EU could add value by supporting this learning process, for instance, by benchmarking existing practices.

Combined solutions

Our analysis of ongoing combined solution projects (e.g. Kriegers Flak, COBRA cable and Murray Firth HVDC Hub) illustrates that the difficulties faced by these projects under the current regulatory frames are tremendous. Therefore, the offshore grid development is currently distorted towards a multiplication of standalone lines, even if there might already be an economic case for combined solutions in some projects.

In the report, we identify five key difficulties that are distorting the development of offshore grids, as well as the respective remedies. They are summarized in the below table:

Key difficulties	Remedies
National frames for transmission investments that are not aligned	Harmonize regulatory frames for offshore transmission investments towards the three guiding principles of an economically sound frame discussed in the report, i.e. planning, competition and beneficiaries pay.
National renewable support schemes that are not aligned	Harmonize the renewable support schemes for offshore wind farms
Multi-stakeholder setting with winners and losers	Facilitate the ex-ante allocation of costs and benefits of offshore transmission investments
Offshore grid technology development constrained by typical R&D market failures	Speed-up offshore grid technology development
Sequential decision process in a context of uncertainty and irreversibility	Adapt the Community-wide transmission planning to offshore grids

We consider that there could be either a soft or a stronger type of EU involvement in the implementation of these remedies. Based on this analysis of the possible role of the EU, we concluded that the EU should support the national and/or regional policy implementation of the remedies with a soft EU intervention; and, where a regional solution is not viable, a stronger EU involvement is already recommended today:

The least regret EU policy on offshore grids	Type of EU involvement	
	Soft	Strong
Indicative guidelines that encourage member states to follow the guiding principles of an economically sound regulatory frame for transmission investments (i.e. planning principle, competition principle, and beneficiaries pay principle), in order to reduce the distortions coming from the national frames	√	
Promote the use of the renewable support scheme flexibility mechanisms for offshore wind farms (i.e. joint project and joint support scheme mechanisms) to reduce the distortions coming from the national support schemes	√	
Organize the approval of transmission investment project packages (i.e. portfolio approach instead of cost benefit allocation arrangements for individual projects), complemented with a new mechanism to implement the beneficiaries pay principle for combined solutions	√	√
Include an offshore grid technology roadmap in the SET-Plan, within an industrial initiative driven by HVDC manufacturers, focused on accelerating offshore grid technology development required for large scale combined solutions (larger than in projects like Kriegers Flak, Cobra, and Moray Firth)		√
Develop improved transmission planning methods and apply them to elaborate a Twenty or Thirty Year Network Development Plan that considers combined solutions		√

Introduction

We subsequently introduce the EU energy policy context of the report and the report scope, analytical frame and structure.

EU energy policy context of the report

The development of an offshore grid may have a significant role in the accomplishment of EU energy and climate objectives. The first EU objective is to have an internal electricity market in the EU. The third energy liberalization package¹ has recently been put into force to complete the ongoing liberalization process, and 2014 has also been put forward as an important milestone. The second EU objective is to achieve the so-called 20-20-20 targets for 2020, as defined by the climate and energy package.² The targets are: to achieve a 20% reduction in primary energy use compared to projected levels for 2020 by improving energy efficiency, to achieve a 20% reduction in EU greenhouse gas emission below 1990 levels, and to have 20% of final EU energy consumption based on renewable energy resources. The third EU objective is to reduce greenhouse gas emissions 80 to 95% below 1990 levels by 2050, which has been decided by the European Council (EC, 2011a).

1. The third package (EU, 2009a) consists of five legislative texts: (1) a Directive revisiting the internal market for electricity; (2) a Directive revisiting the internal market for natural gas; (3) a Regulation on conditions for access to the natural gas transmission networks; (4) a Regulation revisiting the conditions for access to the network for cross-border exchanges in electricity; (5) a Regulation establishing an Agency for the Cooperation of Energy Regulators.

2. The climate and energy package (EU, 2009b) consists of four legislative texts: (1) a Directive revising the EU ETS; (2) an “effort-sharing” Decision setting binding national targets for emissions from sectors not covered by the EU ETS; (3) a Directive setting binding national targets for increasing the share of renewable energy sources in the energy mix; and (4) a Directive creating a legal framework for the safe and environmentally sound use of carbon capture and storage technologies.

The roadmap for a low carbon economy released by the European Commission (EC, 2011b) indicates that achieving these objectives would imply an almost complete decarbonization of the power sector with domestic emission reduction of 93-99% compared to 1990 levels. This transition will require massive investments:

- **Grid investments:** the European Commission has estimated that about 140 billion euro is needed for “*high voltage electricity transmission systems, both onshore and offshore, storage, and smart grid applications at transmission and distribution levels*”, for which it has proposed an “infrastructure package” (EC, 2011c). The package is about streamlining the permit granting procedures, facilitating the regulatory treatment of projects of common interest, and ensuring the implementation of these projects with direct EU financial support where needed. The number one priority project in this package is the Northern Seas offshore grid, i.e. “*an integrated offshore electricity grid in the North Sea, the Irish Sea, the English Channel, the Baltic Sea and neighboring waters to transport electricity from renewable offshore energy sources to centers of consumption and storage and to increase cross-border electricity exchange*”. The European Commission also assigned a so-called European coordinator to the Baltic and North Seas off-shore wind connections, bringing stakeholders together to discuss the issues and identify solutions (Adamowitsch, 2010). This has also led to the establishment of the North Seas Countries’ Offshore Grid Initiative (NSCOGI, 2010), which is currently examining how to overcome the difficulties at the regional level.
- **Grid technology development investments:** in the context of the Strategic Energy Technology Plan (EC, 2009; THINK, 2011a), so-called indus-

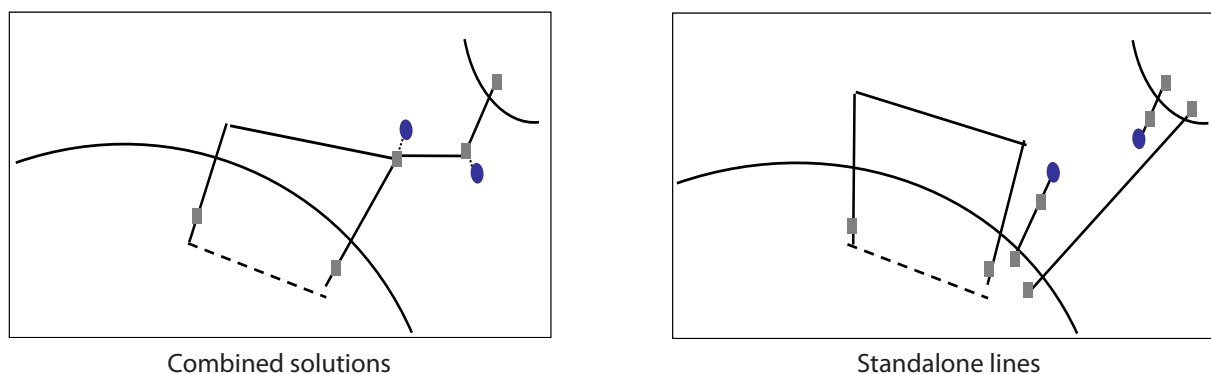


Figure 1 – Alternative offshore grid developments
Legend: ● wind farm; ■ converter station; – HVDC cable; - - HVAC

trial initiatives have been used to come up with technology roadmaps that list the research, development and demonstration activities that will need to be supported to achieve the 2020 and 2050 targets. The roadmaps include activities related to grids, onshore and offshore, but the plan also identified a financing gap of about 47-60 billion euro, calling for more public support from member states and the EU level for joint public private initiatives.

Report scope, analytical frame, and structure

This 5th report of THINK formulates policy recommendations to the European Commission (DG Energy) on offshore grids in the context described above. In this context, there will inevitably be some grid development offshore, but the importance of this development is uncertain (Box 1). Furthermore, it is also uncertain how this offshore grid will develop: there could be a multiplication of standalone lines, which already exist today; and there could also be a transition towards combined solutions, which do not yet exist. The analytical approach in this report is based on this **typology**:

- **Multiplication of standalone lines** (Figure 1, left): in the illustrated case, there are two offshore

wind farms to be connected to shore, interconnection capacity is created between the two onshore grids (with a so-called interconnector), and congestion in one of the two onshore grids is relieved with an offshore line (with a so-called bootstrap). This is achieved with what we refer to in this report as two “farm to shore” investments, and two “shore to shore” investments. The illustration assumes that the individual investments would use High Voltage Direct Current (HVDC) technology so that each of them would require a cable and two so-called converter stations (see annex 2 for more detailed explanations regarding technology).

- **Combined solutions** (Figure 1, right): in the illustrated case, combining the farm to shore and shore to shore investments in a mixed investment would reduce the number of converter stations from 8 to 5³ -and, despite the number of cables being the same as in the non-combined solution, the total cable length decreases. The capacity of the cables and converter stations increases, but given the economies of scale, the effect on total costs of the reduction of number of assets and lengths dominates the capacity effect. The economic case for combined solutions is however very uncertain due to the advanced HVDC hardware and soft-

3. Considering that 2 of these 5 converter stations would be multi-terminal, i.e. having more than one incoming or outgoing cable.

ware that is needed and not yet on the shelves today.

Despite the above introduced uncertainties regarding the development of offshore grids, and especially regarding the development of combined solutions, it is important to proactively assess and adapt where necessary the current EU and national regulatory frames that apply to these investments. Based on this assessment we provide recommendations for the European Commission to take initiatives towards a least regret EU policy.

The report is organized in three chapters, each focusing on the 3 different settings presented above: shore to shore, farm to shore, and combined solutions.

1. Shore to shore standalone lines

In this chapter, we find that the economic features (i.e. the network externalities, cost and technology

uncertainties, and economies of scale) of shore to shore investments are similar to onshore transmission expansions. The offshore regulatory frame can therefore be the same as onshore. The current frames for transmission expansion investments are however economically unsound, both onshore and offshore. This is a problem from the perspective of EU objectives because it leads to underinvestment, while the achievement of these objectives relies on transmission expansion (see introduction).

The chapter is structured in three sections: section 1.1. gives an overview of shore to shore projects, section 1.2. discusses the importance of the three guiding principles for an economically sound regulatory frame, and section 1.3. then assesses the current regulatory frames according to these principles.

Box 1: Uncertainty regarding role of an offshore grid

The possible role of an offshore grid in the future grid is uncertain (Figure 2, and Annex 1 for an overview): ranging from an offshore grid to integrate offshore wind in the North of Europe (e.g. Trade Wind, 2010; Stattnet, 2008; Friends of the Super grid, 2010; and Greenpeace/3E, 2008); to an offshore grid that is part of a larger High Voltage Direct Current (HVDC) overlay grid that also extends across the Mediterranean Sea into North Africa (e.g. Desertec, 2009; EWEA, 2010; EREC/Greenpeace, 2010); up to an offshore grid as part of a futuristic global grid (e.g. WWF, 2010).

Note that these future grid visions have been inspired by the ongoing discussion on the possible pathways towards a low carbon energy system by 2050. In one of our previous reports (THINK, 2011b), we analyzed several of the pathways presented by stakeholders.

According to these stakeholder visions, offshore wind generation will be a significant share of the 2050 installed electricity generation capacity mix: in Eurelectric (2010) this is 8.5%; in ECF (2010) this is between 2% and 15% for scenarios with between 40% and 80% renewable energy; in IEA (2010) this is 7.9%; and in EREC/Greenpeace (2010) offshore wind is said to be important, but it is not quantified.

Note also that on the 2020 horizon, offshore wind farms are expected to increase from the existing 3 GW of installed capacity to about 40 GW, that is, at least, if member states follow the National Renewable Energy Action Plans they recently submitted to the European Commission, in charge of monitoring progress to the binding 2020 targets (EC, 2011d).

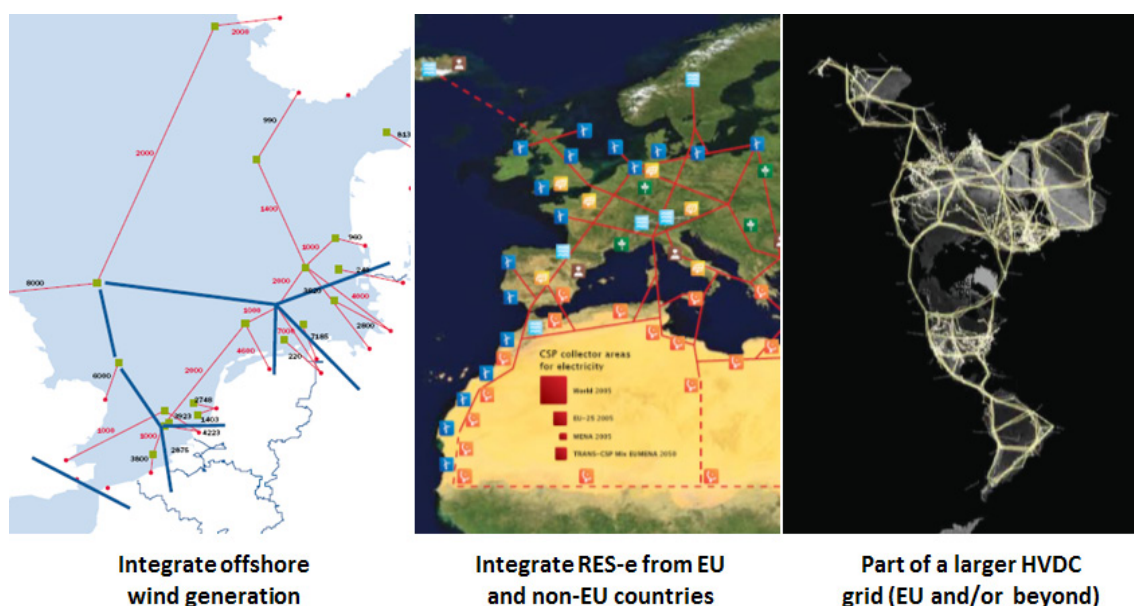


Figure 2 – Future grid visions (Trade Wind, 2010; Desertec, 2009; WWF, 2010)

1.1 Overview of short to shore projects

Figure 3 maps the 29 existing and planned⁴ projects listed in Annex 3. These standalone lines are point to point connections between two onshore grids. Most of the projects are international, connecting two countries, with a few exceptions, such as the interconnections between Sweden mainland and the Gotland Island. Almost every country with a shore has at least one shore to shore line. The total capacity of the projects listed in the annex is 15360 MW.

The projects come in different scales (between 60 and 2000 MW), covering a wide range of distances (between 15 and 580 km), and typically use HVDC technology⁵, with a few exceptions, such as the submarine AC cable between Morocco and Spain.

4. There are many more projects that are in the planning phase. We only included the larger ones, that are already under construction or at an advanced planning stage.

5. Traditionally only HVDC Current Source Converters (CSC) were used, but more recently HVDC Voltage Source Converters (VSC) have also been used.

These shore to shore investments have economic features that are similar to the investments to expand the grid onshore:

- **First are network externalities.** Both onshore and offshore, there is a need to coordinate transmission expansion investments, due to the existing network externalities. Traditionally AC overhead lines have been used for transmission expansions, but increasingly HVDC is considered offshore (for instance, due to the distance limitations of AC cables) as well as onshore (for instance, due to the increasing opposition against traditional overhead lines). Note that the users of an HVDC transmission system can be more easily identified because the flows across can be traced and controlled, which is less the case for AC systems. A nuance is that additional flow controlling equipment can also be installed in an AC grid, which has already been done in some member states (Van Hertem, 2009; Van Hertem et al., 2010).
- **Second are the cost and technology uncertainties.** The social welfare assessments for intercon-

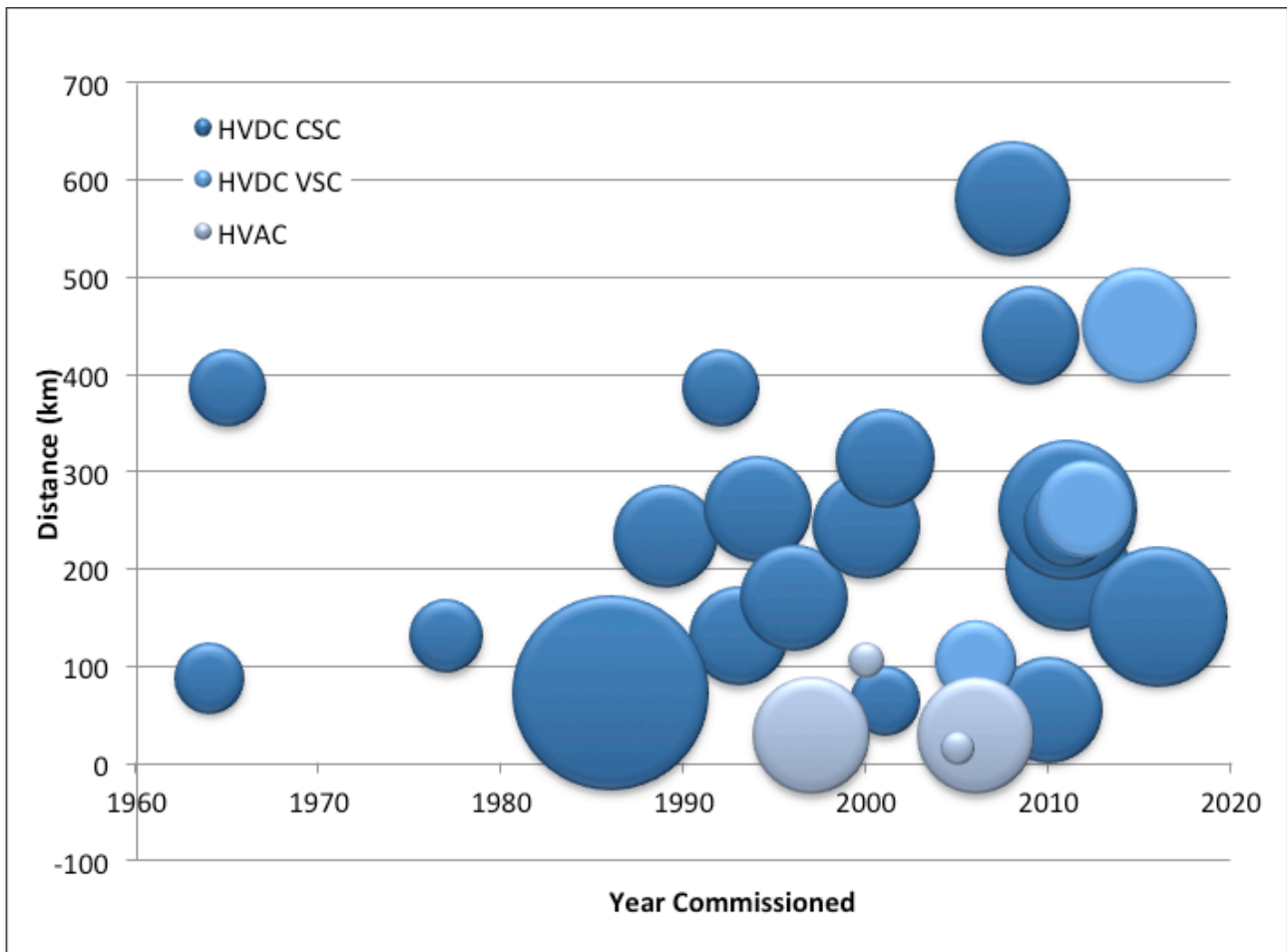


Figure 3 – Mapping of the 29 shore to shore projects (see Annex 3)
(Size of the bubbles represents the power capacity of the connections)

nectors are typically highly uncertain. It is indeed hard to predict future prices and supply and demand curves. Moreover, cost and technology uncertainties are increasing, for instance because of the increasing opposition against the traditional overhead lines. The offshore cost and technology uncertainties are also significant because it concerns a so-called greenfield investment, rather than an incremental investment.

- **Third are economies of scale.** A typical onshore transmission expansion has strong economies of scale, and this is also the case for shore to shore investments.

1.2 Importance of the guiding principles

In this section, we discuss the importance of the three guiding principles for an economically sound regulatory frame for shore to shore investments, i.e. the planning, competition, and beneficiaries pay principles.

1.2.1 Importance of the planning principle

The importance of transmission planning follows from the need to coordinate transmission expansions with the demand for transmission, taking into account the economies of scale and network externali-

ties of transmission investments.

Transmission planning needs to be carried out by an entity that can act on behalf of existing and future grid users in developing transmission services, which is typically the Transmission System Operator (TSO) in Europe.⁶ TSO involvement in both connection and transmission planning also ensures that there is coordination between the two, onshore as well as offshore. The role of the TSO is to present the costs and benefits of the proposed investments to the regulator; and the regulator then decides whether or not to approve these investments. Approved investments go into the so-called Regulated Asset Base, which implies that they receive a regulated rate of return. The role of the regulator is therefore to make sure that grid users get value for money.

More recently, regulatory theory (and practice) is also emphasizing that participation of grid users into the procedure is needed to reduce the risk of stranded costs, and to give the regulator confidence that the demand for transmission capacity, as presented by the TSO, is real (Littlechild & Cornwall 2009, Littlechild & Skerk 2008, Brattle Group, 2007b; Hogan, 2011). Indeed, the regulator cannot observe if the regulated company is investing too much or too little because the impact of the investments on the performance of the network cannot be clearly observed. Furthermore, the demand for transmission services is quite uncertain so that the risks for stranded costs are high.

1.2.2 Importance of the competition principle

Competition can be introduced through tendering,

6. Note that the TSOs that are common in Europe own and operate the grid, but there are also alternative institutional arrangements to organize transmission, like the model of an Independent System Operator (ISO) that is separated from the transmission owner (TO).

which is especially important when there are cost and technology uncertainties (Rious 2006, Alexander 2006). Tendering for the participation of third parties in part of the investment decisions incentivizes innovation and reduces the problem of information asymmetry between the TSO doing the planning and the regulator.

Note that transmission expansions onshore, contrarily to offshore, are typically incremental investments in an existing grid, which can be many small investments that are more difficult to delegate. The coordination cost of tendering could therefore be higher than the potential gain from adding competition. But an element of competition can also be added by allowing third parties to propose projects to the regulator so that the TSO can be contested.

1.2.3 Importance of the beneficiaries pay principle

Making the beneficiaries pay is important to signal the costs of their demand for transmission services. The users of a transmission line are important beneficiaries of the line. By letting these users pay for their usage of the line, they internalize the costs into their generation and consumption decisions that imply a certain demand for transmission services on that line. This can be implemented by auctioning transmission access rights or by internalizing the allocation of transmission capacity into the organized electricity market.

The revenue generated in this way would however not be enough to pay for the level of investment that maximizes the costs and benefits of transmission expansions. As demonstrated in Pérez-Arriaga et al. (1995), this is because there are economies of scale in transmission, investments are typically lumpy, and there

are reliability constraints, and unavoidable planning mistakes.

In other words, transmission investments generate public good type of benefits, such as improved system supply security, and stronger competition among generators so that the usage of the network is not enough to support the optimal level of investment (Benjamin, 2007; Latorre et al., 2003; Borestein et al., 2000; Sauma-Oren, 2007; Sun et al., 2004). Therefore, at least part of the costs needs to be covered with transmission tariffs. Note that this is then also the reason why the merchant business model for transmission that solely relies on revenues from allocating transmission access rights will lead to underinvestment (Hauteclouque and Rious, 2009; Sauma and Oren, 2009; Stoft, 2009).

Tariff design is then about allocating costs to different types of grids users (e.g. consumers, generators, and

storage) with different usage profiles (e.g. energy, capacity, and load profile). Box 2 elaborates on another issue regarding transmission charging, which is the importance of providing economic signals to generators in transmission tariffs.

To sum up, in order to minimize the total cost of the investment in generation and its complementing transmission investment, it is important to follow the above discussed guiding principles for an economically sound frame, as recommended by regulatory theory (see also: De Jong and Hakvoort, 2006; Hogan, 2011; RealiseGrid, 2009; Sauma and Oren, 2006, 2007; Stoft, 2009; Joskow-Tirole, 2005; Olmos and Pérez-Arriaga, 2009; Pérez-Arriaga and Smeers, 2003; Joskow, 2009).

Box 2: Transmission charging

see THINK (2012) for a more detailed discussion of transmission tariff design).

Locational signals can be given through the auctioning of transmission access rights. Indeed, under nodal pricing, the costs of transmission constraints are embedded in the electricity prices, which is not the case when uniform pricing is applied. Locational signals can also come from transmission tariffs. Indeed, tariffs allocate costs to different categories of grid users, which implies deciding which costs to allocate to consumers versus generators; to high voltage versus low voltage grid users; to different usage profiles (energy versus capacity); and to grid users in different locations.

In practice, many member states however preferred the simplicity and transparency of postage stamp tariffs, i.e. without locational differentiation. Another rea-

son is that the tariffs in most member states allocate most or all costs to consumers, while locational signals in tariffs would be more useful if also generators would be exposed to them. Note that allocating fixed cost to less elastic players, which in the electricity system are the consumers, is the economic principle of Boiteux 2nd Best/Ramsey pricing (Greer, 2010).

Note however that the elasticity of the load increases with the new developments of distributed generation and storage. Note finally that there is an EU cap on the share of transmission costs that can be allocated to generators (G-component), which has been introduced to limit the internal market distortions from having non-harmonized G-component in national transmission tariffs.

1.3 Assessment of the current regulatory frames for shore to shore investments

In this section, we assess the current regulatory frames for shore to shore investments according to the three guiding principles of an economically sound frame.

1.3.1 Assessment according to the planning principle

In Europe, transmission planning is done by national TSOs and approved by national regulatory authorities, while the national decisions also have implications for grid users across the border that are not taken into account in the decisions. Coordination between national investments is also limited. In other words, despite the strong interdependencies between national grid investments, planning is currently mainly done at the national level, which is not in line with the planning principle.

An exception is the indicative Community-wide planning procedure that has recently been introduced by the third package – the Ten Year Network Development Plan (EU, 2009a). The plan will be made by the newly created European Network of Transmission System Operators for Electricity (ENTSO-E). ENTSO-E is an official body of TSOs that is mandated to carry out certain tasks that have been assigned to TSOs by the third package. This institution has also replaced the former voluntary associations of European TSOs called ETSO, and regional TSO associations, such as UCTE for the Continent and Nordel for Scandinavia.

The pilot version of the TYNDP published in March 2010 was however mainly bottom-up, while future versions are expected to combine such an approach with a more top-down approach starting from the Community wide interests rather than the national

interests to make the TYNDP. Finally, note that public consultation procedures on the TYNDP are required, which is also an important step towards the planning principle.

Note also that the newly created Agency for Cooperation of Energy Regulators (ACER) is to provide an opinion on the plan that will be presented by ENTSO-E on a biannual basis starting from March 2011. ACER can also recommend amendments to the national plans in case of inconsistencies, and national regulatory authorities are required to check the consistency of their national plans with the TYNDP.

1.3.2 Assessment according to the competition principle

In most EU member states, the only way for third parties to contest the regulated transmission expansion business of the TSOs, is to apply for a so-called exemption for a merchant project (option 1), with the exception of the UK and Belgium where it is also considered for regulated projects (option 2).

First option is the use of exemptions for merchant projects that are negotiated on a case-by-case basis (Kessel et al., 2011). These projects can however only be exceptionally approved under the EU regulatory frame. For instance in the case of the Estlink project between Finland and Estonia (commissioned in 2006, 105 km, and 350 MW), a consortium of generators has been allowed to construct an interconnector. Priority access to this interconnector has been granted to these generators for a period that is limited in time. After this period, the ownership will be transferred to the national TSOs and the regulated third party access rules will apply. The reason to grant the exemption has been that the benefits of the project were uncertain, while the impact on the Estonian transmission tariff could have been significant if a

regulated rate of return would have been guaranteed to the project. Relaxing the regulatory conditions for merchant projects could improve the contestability of the transmission expansion business, but the merchant business model cannot support an adequate level of investment (see section 1.2.3).

Second option is to allow third parties to develop projects that are (partly) financed with transmission tariffs. For instance in the case of the Nemo project between the UK and Belgium, this is currently considered (expected commissioning 2016-2018, 100 km, 1000 MW). Note that it is the first time that such a scheme is possible in the EU, but in the US this model is more common; see for instance the Trans Bay Cable project (Coxe and Meeus, 2010).

1.3.3 Assessment according to the beneficiaries pay principle

The allocation of costs and benefits of transmission expansion investments in Europe is purely national for investments within a member state, and for investments between member states there is typically an ad-hoc bilateral agreement. For instance in the case of NorNed (commissioned in 2008, 580 km, and 700 MW), the Norwegian TSO and the Dutch TSO proposed to their national regulatory authorities that they would each bear half of the total project cost. The regulators have approved these costs, meaning that they are covered by the national transmission tariffs in case the revenue from allocating the usage rights of the interconnector would have been lower than the costs of the project. Other beneficiaries did not participate in the development of this project, and as a result the project has been designed to optimize the national interests of the two countries that are being interconnected, while this project received significant EU support (Meeus et al., 2004).

Community-wide indicative planning therefore needs to be backed by an ex-ante allocation of costs and benefits that is facilitated at EU level to go beyond the ad-hoc bilateral agreements, as in NorNed, that are suboptimal from the European point of view. This facilitation could include a new mechanism for infrastructure investments that would be ex-ante rather than ex-post,⁷ and a portfolio approach that would reduce the need for compensation by approving many projects at the same time so that the cost and benefit asymmetries are less problematic as they are for individual projects (see THINK, 2012). The recently proposed infrastructure package (EC, 2011c) is a step in this direction. Note that EU funding⁸ would not necessarily be needed if the ex-ante allocation of costs and benefits would be adequately facilitated at EU level.

To sum up, the current regulatory frames applied to shore to shore investments are mainly national and economically unsound. The NorNed and Estlink projects are illustrative for the resulting suboptimal investments, while the frame that has been designed for the Nemo project seems to be a step towards the guiding principles (Box 3). This is a problem from the perspective of EU objectives because it leads to underinvestment, while the achievement of these objectives relies on transmission expansion investments

7. Note that there is an inter-TSO mechanism that defines compensation rules between TSOs whose grid users cause transits and TSOs that incur costs due to transits (FSR, 2005; Olmos, 2007), but it is ex-post based and limited to operation costs such as losses. Moreover, currently ITC mechanism is limited to the allocation of 100 M€, which is a very small figure compared to the needed EU transmission investments.

8. Examples of EU funding are the Trans-European Network program (EU, 2003; EU, 2004; EU, 2009), the European Economic Recovery Program (EC, 2008) and the European Investment Bank. EU funding has been traditionally used to finance feasibility studies for projects of common European interest (typical functioning of the Trans-European Network Policy until the Recovery Program) and has also given limited support to the construction of these projects, but this support is marginal in comparison with the scale of the investments that are needed.

Box 3: Summarizing the assessment of the regulatory frames for shore to shore investments

NorNed (Meeus et al., 2004; NornedAuction, 2011; TenneT, 2004), i.e. project between Norway and the Netherlands: nationally planned (first principle: orange); the design and development of the project has not been subjected to competition (second principle: red); bilateral ad-hoc agreement to split the costs between the involved countries (third principle: orange).

Estlink (Aarna, 2006; Nordic Energy Link SA, 2011; Vandezande et al., 2006), i.e. project between Finland and Estonia: nationally planned (first principle: orange);

merchant project (second principle: orange); merchant project (third principle: red).

Nemo (Ofgem and CREG, 2011; Crouch, 2011), i.e. project between the UK and Belgium: nationally planned (first principle: orange); the design and development of the project will be subjected to competition (second principle: green); bilateral ad-hoc agreement to split the costs between the involved countries (third principle: orange).

	NorNed	Estlink	Nemo
First Principle (planning)	Orange	Orange	Orange
Second Principle (competition)	Red	Orange	Green
Third Principle (beneficiaries pay)	Orange	Red	Orange

(see introduction). This problem is however not specific to offshore, so that the ongoing process of the third package and the infrastructure package to find a solution for onshore would also help solve the shore to shore problem.

2. Farm to shore standalone lines

In this chapter, we find that: farm to shore investments are featured with stronger network externalities, higher cost and technology uncertainties, and larger economies of scale than the investments to connect a generator onshore. The regulatory frame for the connection of a generator onshore therefore needs to be fine-tuned for offshore investments. The current frames for connecting generators are how-

ever economically unsound, both onshore and offshore. Offshore this is more problematic because the economic features mentioned above are stronger, but this might not be a problem from the perspective of EU objectives since the negative economic effects are mainly local.

The chapter is structured in three sections: section 2.1 gives an overview of farm to shore projects, section 2.2 discusses the importance of the three guiding principles for an economically sound regulatory frame, and section 2.3 then assesses the current regulatory frames according to these principles.

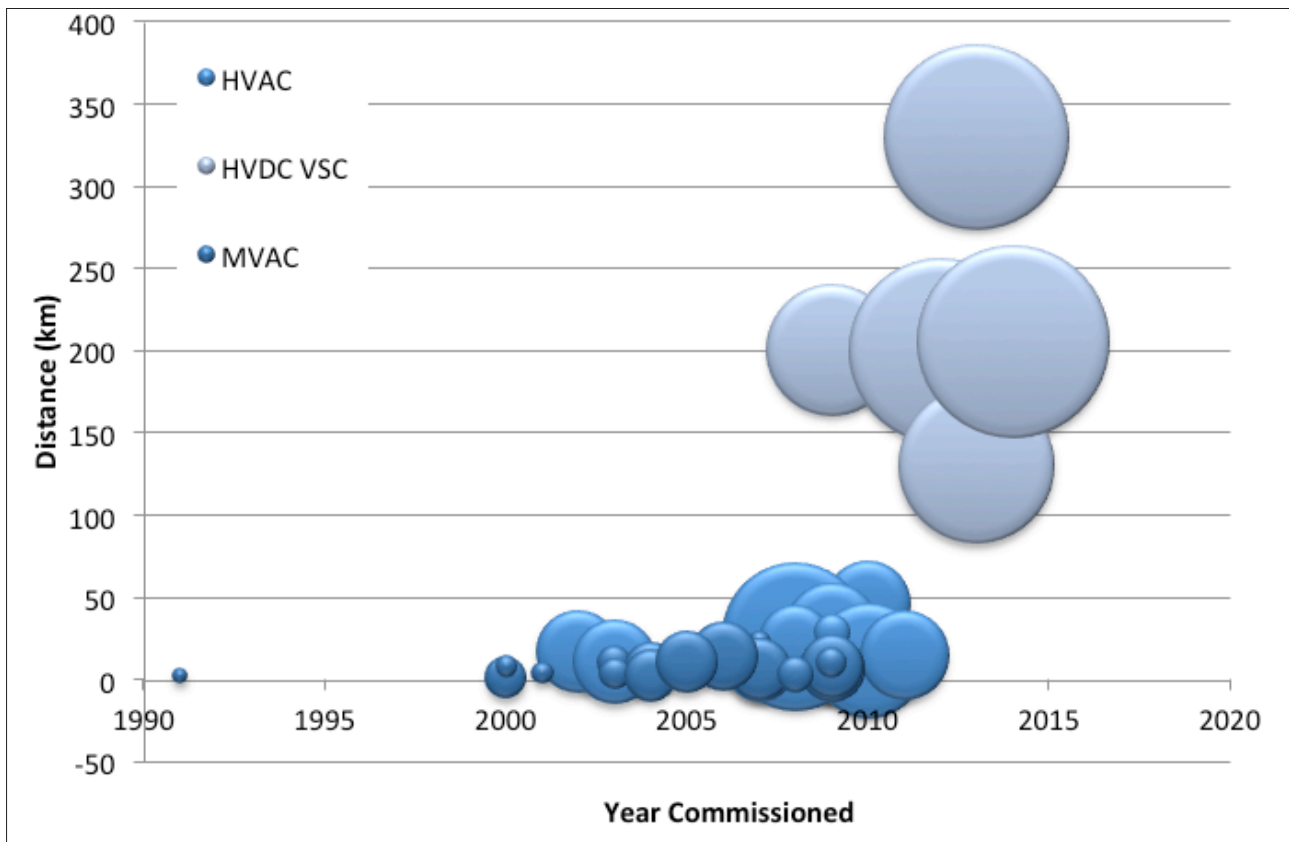


Figure 4 – Mapping of the 53 farm to shore projects (see Annex 4)
 (Size of the bubbles represents the power capacity of the connection)

2.1 Overview of farm to shore projects

Figure 4 maps the 53 existing and planned⁹ projects listed in Annex 4. These standalone lines are the point to point connections of offshore wind farms with the transmission grid. Within these lines, we can distinguish two types of projects: old and new.

- **Old type of projects** are relatively close to shore (between 0.01 km and 53 km, with a median value of 7 km), relatively small scale (between 2 and 504 MW), and using a Medium or High Voltage Alternative Current (MVAC or HVAC) transmission system.

9. There are many more projects that are in the “planning” phase. We included a few examples that are relatively more advanced and that are illustrative for what we refer to with “new” type of farm to shore investments (see for instance, <http://www.lorc.dk/Knowledge/Offshore-renewables-map/Offshore-wind-farms>).

- **New type of projects** are relatively large scale (between 400 and 864 MW)¹⁰, far from shore (between 130 km and 330 km), and using a HVDC VSC transmission system. Figure 4 only includes new type of farm to shore investments located in Germany, but they are also expected in other member states. For instance in the UK, the most recent round of concessions allocation focused on this type of projects.¹¹

10. Note that 7 MW HVDC VSC Tjaereborg project in Denmark has been developed to demonstrate on a small scale the application of this new technology for connection of large-scale offshore wind farms and with distances above 50 km from the coastline ([http://www05.abb.com/global/scot/scot221.nsf/veritydisplay/0036819698281f84c1256fda003b4d32/\\$file/tjaereborg.new.pdf](http://www05.abb.com/global/scot/scot221.nsf/veritydisplay/0036819698281f84c1256fda003b4d32/$file/tjaereborg.new.pdf))

11. Round 3, of the Crown Estate tender in 2009, allocated 9 concessions representing a total of 32.2 GW (http://www.the-crownestate.co.uk/our_portfolio/marine/offshore_wind_energy/round3/r3-developers.htm). Almost 20 GW of this total, which will be commissioned after 2015, corresponds to new type of farm to shore (large scale, far to shore, HVDC connection) (see for in-

Note that the total capacity of the projects listed in the annex is 7,129 MW. The EU member states with offshore wind farms include Belgium (195 MW), Denmark (875 MW), Finland (32 MW), Germany (3,560 MW), Ireland (25 MW), the Netherlands (247 MW), Norway (2 MW), Sweden (163 MW), and the UK (2,029 MW).

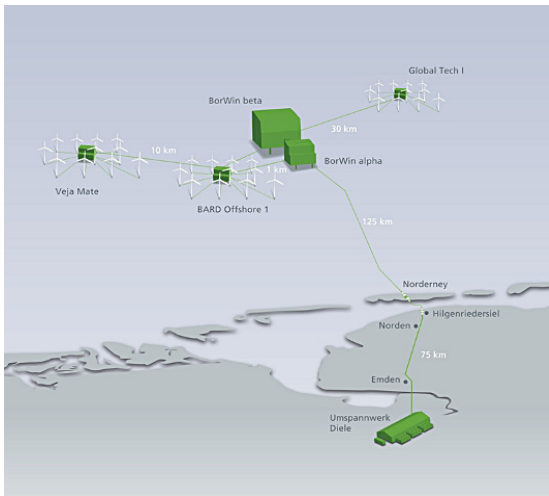
These farm to shore investments, especially the ones classified as new type, have economic features that are stronger than the features of the investment to connect a generator onshore, which we will illustrate with the Borwin project (Figure 5, and the new type of projects in Figure 4).

- **First are stronger network externalities.** Most generators onshore can be located near the existing transmission grid and can be relatively easily connected. Indeed, grids are normally well developed and meshed onshore. Moreover, conventional generators are mainly thermal gas power plants, which have a certain flexibility concerning the choice of their location. Exceptions onshore can be large hydro or onshore wind farms located far away from the existing onshore transmission grid. Offshore, these exceptions are however becoming the rule. In the case of Borwin, three offshore wind farms with a total installed capacity of 1200 MW at 200 km distance from shore needed to be connected to the onshore transmission grid. Close to shore the existing grid is typically weak because generation used to be located inland, and it is also already congested because it has become more favorable to locate onshore generation in this area, e.g. there are more favorable conditions for onshore wind farms, and harbors are attractive to reduce the cost of importing coal. Therefore it

is more likely that grid reinforcements are needed when connecting an offshore wind farm.

- **Second are stronger cost and technology uncertainties.** As said above, most generators can be connected relatively easily. Indeed, a typical connection is relatively cheap, and uses well-known AC transmission systems. In the case of Borwin, the offshore wind farms have however been connected using the less known HVDC VSC systems. In general, the experience offshore with the installation, operation and maintenance of transmission assets is much more limited than onshore. For instance, the salted water environment requires the components to be more resistant to corrosion. Moreover, offshore transmission systems are built from scratch so that there are more degrees of freedom in the investment decision that could be explored, i.e. greenfield investment.
- **Third are stronger economies of scale.** There are always economies of scale in transmission investments (i.e. cost per unit of transmission decreases for increasing capacities), but there are not necessarily several generators asking to be connected in same area around the same time. This can be exceptionally the case onshore, but offshore this is typically the case. Indeed, in the case of Borwin, three offshore wind farms share a connection to shore. The HVDC system that has been developed consists of a DC cable with two converter stations, one to convert the AC output of the wind turbines into DC, and one to reconvert the DC output of the cable into the AC of the existing onshore grid. By coordinating the connection of the three wind farms in Borwin in two phases only three converter stations and one cable to shore will be used, instead of six stations and three cables (i.e. a 400 MW connection was commissioned in 2009, which is expected to be upgraded in 2012 with an additional 800 MW for a total cost of about 1200

stance: www.thecrownestate.co.uk/round3_connection_study.pdf.



5a. Schematic representation of Borwin – phases 1 & 2



5b. Borwin Alpha, VSC HVSC converter station

Figure 5 – Borwin: the project in pictures

Sources: TenneT (2010) and ABB (2011)

M€). In other words, the project has benefited from having several wind farms sharing their connection to shore, which is referred to as wind farm clustering.

Note also that the transmission investment to connect an offshore wind generator is a significant part of the total project cost, which is much less the case for the connection of onshore generators. For instance, grid connections for onshore wind account for 5 to 10% of the total project cost, while offshore this share is between 15 and 25%. Grid connection costs depend on the distance to the connection point, type of terrain to be crossed, the voltage level of connection, the availability of infrastructure such as transformer stations or substations and on the technical requirement as laid out in national regulations. See, for instance, Green-Vasilakos (2011), Weißensteiner et al. (2011), Obersteiner et al. (2006), Swider et al. (2008), Auer et al. (2007), and EWEA (2009).

2.2 Importance of the three guiding principles

In this section, we discuss the importance of the three guiding principles for an economically sound regulatory frame for farm to shore investments, i.e. the planning, competition, and beneficiaries pay principles.

2.2.1 Importance of the planning principle

The importance of connection planning follows from the economies of scale that can be achieved by coordinating the connection of generators that are asking to be connected in the same area around the same time. The coordination can be beneficial for the infrastructure to connect the generators to the existing grid, and for the reinforcements that are needed in this grid.

Then, the investment decisions need to be made by an entity representing several generators, including those that are asking to be connected today and, those that are expected to need connection tomorrow, and

other grid users. Hence, it suggests the proactive involvement of TSOs. It also suggests the participation of generators having better information about their demand for transmission services, for instance, by organizing group connection procedures, or auctioning of connection slots.

2.2.2 Importance of the competition principle

Tenders can be organized to introduce competition for who is allowed to own, build, and operate the transmission assets to connect a generator to the existing grid.

The benefits of competitive tendering include incentivizing innovation in the design of a transmission

connection, including the technological system and the contractual arrangements to share the risks between the relevant stakeholders. Benefits can also include the reduction of information asymmetry between the regulatory entity and the regulated TSO. Tendering should however only be used when these benefits outweigh the additional costs related to the organization and administration of the tender.

2.2.3 Importance of the beneficiaries pay principle

Making the beneficiaries pay is important to signal the costs of their demand for connection services. By letting them pay for their connection, generators internalize the cost of the total investment in their gen-

Box 4: Connection charging

Interaction with other network cost signals that can be given to generators: connection charging options are typically analyzed in combination with different energy pricing and network tariffs designs. Some propose deep charges combined with short run nodal/zonal energy prices (see for instance Newbery, 2011), others propose super shallow connection charges combined with locational long run network tariffs, (see for instance Bell et al 2011, Baldick et al. 2011). For instance in the UK, super shallow connection charges are currently applied to generators, while generators pay for part of their connection because part of the network costs are recovered from generators (so-called G-component in transmission tariffs with locational signals, see Box 2).

Interaction with renewable support schemes: special rules for renewable energy generation, like connection priority (means that a renewable generator can short-cut the queue of first come first serve con-

nection regime) or access/dispatch priority (means that in case of limited access capacity at one particular moment, renewable generators have the priority to access to the network), and exempting these generators from connection charges are being used to facilitate the integration of these technologies. This is however not economically sound and a better way to support renewable generation would be to expose them to the same economic signals as conventional generators regarding when and where to connect, but to include a component for an efficient connection investment in their support scheme. In support schemes, such as feed-in tariffs or premiums, the component can be directly included by increasing the level of support, while in green certificates schemes it can be included indirectly by increasing the penalty or the price cap of green certificate. Clearly, this would be more cost reflective and transparent (see for instance Hiroux and Saguan, 2010; Madrigal and Stoft, 2011; and the ongoing CEER public consultation, 2011).

eration investment decisions. Generators can indeed have several options on where to locate and, even if their decision on where to locate is dominated by other factors, making them pay for their connection can incentivize them to proactively participate in connection planning, which can reduce the cost of their connection.

Box 4 elaborates on two additional issues regarding connection charging, which is its interaction with other network cost signals that can be given to generators; and its interaction with renewable support schemes for renewable energy technologies.

To sum up, in order to minimize the total cost of the investment in generation and its complementing transmission investment, it is important to follow the above discussed guiding principles for an economically sound frame, as recommended by regulatory theory (see also: Sauma-Oren, 2006a, 2006b, 2007; Rious et al 2010; Madrigal-Stoft, 2011; Groppi-Fumagalli 2011.)

2.3 Assessment of the current regulatory frames for farm to shore investments

In this section, we assess the current regulatory frames for farm to shore investments according to the three guiding principles of an economically sound frame.

2.3.1 Assessment according to the planning principle

In Europe, connections are dealt with on a first-come-first-serve basis by the national TSOs, and the participation of generators is limited. Such a reactive connection planning strategy whereby transmission follows generation is increasingly problematic because most plants that are currently constructed, such

as gas plants and renewable energy plants, are relatively quick to market, while transmission is facing increasing opposition so that its reaction comes too late if it continues to follow generation.

A more proactive planning would imply that the TSO anticipates possible investments by starting to develop transmission projects, by applying for the necessary permits e.g., to reduce the time to commission a transmission investment, if and once approved. This is however only possible if the regulatory frame allows/encourages the TSO to make such anticipatory costs. Especially offshore, it is important to be proactive due to the stronger economies of scale and network externalities.

The German frame illustrates how advanced connection planning can be implemented. The Borwin project was indeed only possible because the farm to shore investment made in 2009 created overcapacity to be used by an offshore wind farm expected in 2012. In other words, the regulatory frame has encouraged the TSO to propose, and the regulator to approve, an anticipatory investment that is expected to be beneficial in the future, while there is also a risk for stranded assets in case the expected offshore wind farm development does not materialize. Moreover the so-called DENA studies in Germany (DENA, 2005, 2010, 2011), illustrate how to plan for the impact of onshore and offshore wind farms on the existing grid.

Note that the German regulatory frame also includes an interesting role for the Federal Maritime and Hydrographic Agency (BSH, 2011). The Agency produces an annual report, with the identification of existing and planned offshore facilities, in order to facilitate maritime planning. TSOs use this information to perform their connection planning.

2.3.2 Assessment according to the competition principle

With the exception of few member states, as for instance France (Rious, 2006), the transmission investment to connect a generator in Europe can only be done by TSOs that cannot be contested neither in the design nor in the development of connections.

This will be increasingly problematic as the amount of new type of generators that needs to be connected will probably increase in order to comply with the 2020 and 2050 energy policy ambitions. This is especially the case offshore because the cost and technology uncertainties that apply to farm to shore investments are stronger than for the connection of a generator onshore.

The UK frame illustrates how competitive tendering can be implemented (Ofgem, 200; 2010; 2011a and b). The tender is envisaged to encompass the building, ownership, and operation of the transmission systems that connect offshore wind farms to shore. The winner of the tender is then the most interesting proposal to provide these transmission connection services for the lowest regulated income. Note that generators can also choose not to tender, but to do the farm to shore investment themselves.

The first so-called Offshore Transmission Owner (OFTO) license has been awarded in 2010 for the project Robin Rigg, which a 180 MW offshore wind farm at 8 km from shore. The Robin Rigg wind developer had already started to develop the farm to shore investment under the previous regulatory frame so that this tender has only been about transferring the ownership and operation of the transmission assets. For the first tender round that included Robin Rigg and other projects for a total value of 1.1bn GBP, Ofgem has estimated savings to be in the range of 350mn GBP thanks to market entry and the sourcing of funds.

2.3.3 Assessment according to the beneficiaries pay principle

In Europe, super shallow charging whereby the generator almost does not pay for its connection is not uncommon.¹² For instance, renewable generators are often (partly) exempted from connection charges. This is problematic because it implies that these generators do not take into account the cost of connection in their investment decisions. Especially offshore this is an issue because it also hinders the implementation of more advanced connection planning, which is opportune offshore.

The UK and Swedish frames illustrate how offshore wind farms can be charged for the costs of their connection.

To sum up, the current regulatory frames for farm to shore investments are mainly national and economically unsound. Nonetheless, pioneering member states have already recognized that this is especially problematic offshore, and have started to experiment with fine-tuned frames. The models of Germany, the UK and Sweden are good examples of how the first, second, and third guiding principle of an economically sound frame can be implemented, respectively, but they are unsound from the perspective of at least one of the other principles (see Box 5). This is however not necessarily a problem from the perspective of EU objectives because the negative economic impact is mainly local.

12. Note that some member states also apply deep connection cost charging, which implies that the generators also pay for the grid reinforcements that are sometimes needed in the existing grid when connecting a generator. For instance, Finland, Czech Republic and Luxembourg apply deep connection charging (Realisegrid, 2010). The debate shallow versus deep often comes down to where to put the border between the grid and the connection (Barth et al, 2008; Jamasb et al, 2005; Weißensteiner et al, 2011).

Box 5: Summarizing the assessment of the regulatory frames for farm to shore investments

In Germany (DENA, 2011; TenneT, 2010): there is advanced connection planning (first principle: green); farm to shore investments are done by the TSOs, lacking competition (second principle: red); and offshore wind generators do not pay for their connection (third principle: red).

In Sweden (Swedish Gov., 1997): there is no advanced connection planning (first principle: red); but offshore wind developers build their own connection so that it is an activity open for competition (second principle: green); and developers also pay for their self-developed connection (third principle green).

In the UK (National Grid, 2010a; Ofgem, 2009, 2011a, 2011b): there is no advanced connection planning, although the goal is to go in this direction by the coordination of the onshore TSO and the OFTO (first principle: orange); there is a competitive tender process for farm to shore investments (second principle: green); and offshore generators pay for their connection (third principle: green). Note that the UK has super shallow connection charging, but offshore wind farms anyway pay for their connection because the UK transmission tariff allocates part of the network costs to generators (there is a 30% so-called G-component), and for offshore generators this includes 100% of the cost of their connection to shore.

Note that the above assessment does not necessarily imply that the UK regime will be the best performing regime for two main reasons. First reason is that the relative importance of the principles remains to be seen, it could for instance be that the first principle is the most important one so that the German model could outperform the Swedish and UK model. Second reason is that we assess the regulatory frame for the connection of the offshore wind farms, while performance will also depend on other factors, such as the renewable support scheme for offshore wind.

	Germany	UK	Sweden
First Principle (planning)	Green	Yellow	Red
Second Principle (competition)	Red	Green	Green
Third Principle (beneficiaries pay)	Red	Green	Green

3. Combined solutions

Combined solutions are mixed farm to shore (connection of offshore wind farms) and shore to shore (creation of interconnection capacity) investments. This type of offshore grid development is an alternative to standalone solutions and so it implies differ-

ent recommendations in terms of regulation and EU involvement.

The chapter is structured in three sections: section 3.1 gives an overview of combined solution projects, section 3.2 discusses the development of these proj-

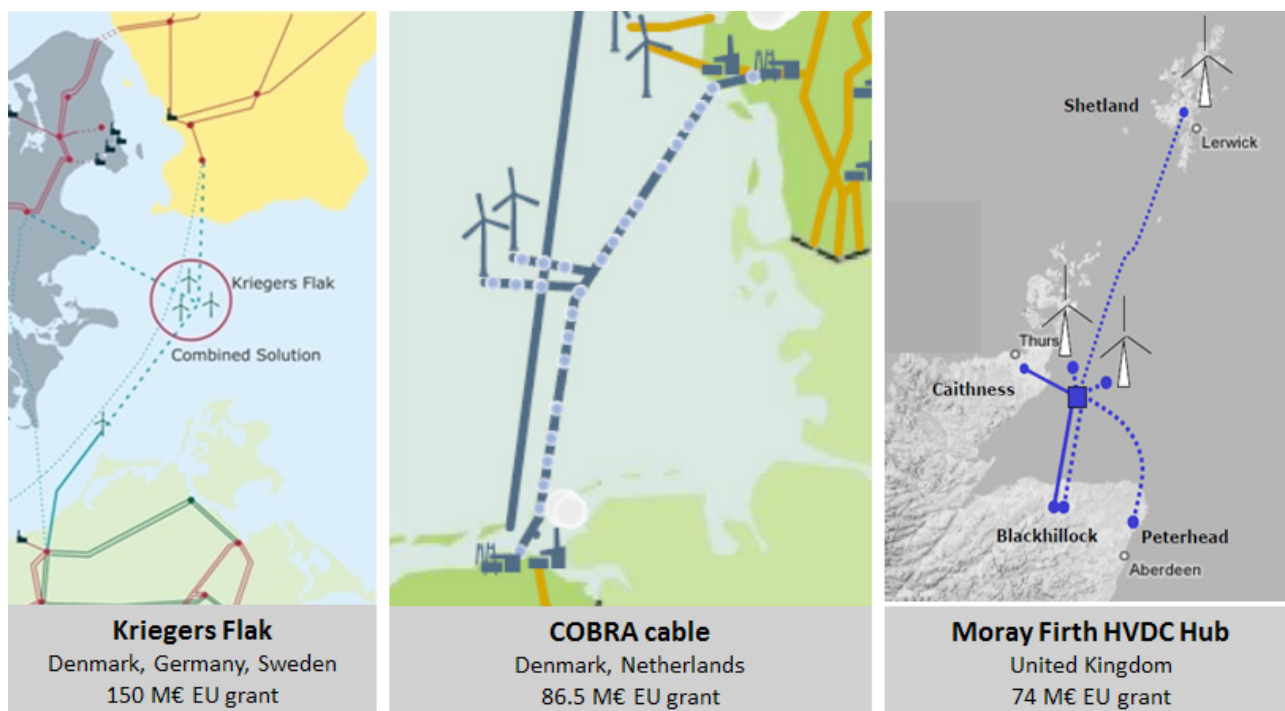


Figure 6 – Kriegers Flak, Cobra cable, and Moray Firth
(based on Jørgensen, 2011; Van Dijk and Vilhelmsen, 2011; Neilson, 2011)

ects under the current regulatory frames, identifying the main difficulties and possible remedies, and section 3.3 discusses how the EU could implement the possible remedies.

3.1 Overview of combined solution projects

Our overview focuses on the three ongoing combined solution projects that have received EU funding from the European Economic Recovery Program for being first of a kind projects, i.e. Kriegers Flak (grant of 150 M€), Cobra cable (grant of 86.5 M€), Moray Firth HVDC Hub (grant of 86.5 M€) (Figure 6).

Table 1 provides the basic characteristics for each of these three projects, i.e. the year they are expected to be commissioned, the countries involved, the total installed capacity of the offshore wind farms they are expected to connect, and the total amount of inter-

connection or bootstrap capacity that is expected to be created by the combined solution.

In what follows, we further introduce the projects and discuss what is known and uncertain about their economic case:

- Kriegers Flak** is a project planned by the Danish TSO (Energinet.dk), a German TSO (50-Hertz), and the Swedish TSO (Svenska Kraftnätt). They studied a combined solution, involving the connection of up to 1600 MW of offshore wind farms in Danish, German, and Swedish waters, with the creation of interconnection capacity (Energinet.dk, 2009; E-Bridge, 2010; Jørgensen, 2011). The feasibility study argues that, in this specific case, there is a net gain, but the study did not demonstrate that the net gain of this combined solution is superior to the net gain of a multiplication of standalone lines: *“It is not within the scope of this*

Table 1: Combined solution project summary

	Kriegers Flak	Cobra cable	Moray Firth HVDC Hub
Year commissioned (expected)	2016	2016	Originally 2013, now expected for 2015-2018
Countries involved	Denmark, Germany, Sweden	Denmark, Netherlands	UK
Interconnection capacity	Only when the wind does not blow	700 MW	To be determined
Bootstrap capacity	No	No	To be determined
Offshore wind farm capacity	up to 1600 MW	Optional	up to 2500 MW

pre-feasibility study to make detailed comparisons between a combined solution at Kriegers Flak and other ways of providing additional transmission capacity across the Baltic Sea.”

- **Cobra cable** is a project planned by the Dutch TSO (Tennet) and the Danish TSO (Energinet.dk) to interconnect Denmark with the Netherlands with a capacity of about 700 MW, with an option to also connect offshore wind farms at a second stage (TenneT, 2011; Van Dijk and Vilhelmsen, 2011). OffshoreGrid (2011) studied the economic case of the Cobra cable between Denmark and the Netherlands. Teeing-in a German wind farms to the Cobra cable is identified as beneficial from the point of view of European welfare, i.e. the most interesting option that is suggested by this study is to add 1300 MW of offshore wind farms to the 700 MW Cobra cable. The study is however not clear on how sensitive this positive result is to the significant cost and technology uncertainties that apply to these projects.
- **Moray Firth HVDC Hub** is a project planned by the Scottish TSO (SSE) to connect existing and planned offshore wind farms to shore (up to 2500 MW), and simultaneously interconnect the on-shore grid of the mainland in Scotland to the grid

of the Shetland Islands (located in the North East of the country) (SSE, 2010; Neilson, 2011). The commissioning has recently been delayed from the previously stated 2013 to between 2015 and 2018, which is an illustration of the level of uncertainty in this type of projects.

Note finally that in existing HVDC systems, the whole infrastructure stops working if a fault occurs in one of its components. A more sophisticated operation of HVDC systems would require more advanced grid technology that has not yet been tested in practice, i.e. including hardware (e.g. HVDC circuit breakers) and software (e.g. HVDC control systems). In relatively small offshore grids, like the above discussed projects, it would still be manageable to shut down the entire grid to isolate a fault before reactivating part of it, so that combined solutions might already be opportune today. They may also become opportune on a wider scale in the future, but this will depend on how this advanced grid technology will develop.

To sum up, the projects that we analyzed in this section have not yet demonstrated that there is an economic case for combined solutions. In the case of Kriegers Flak and Moray Firth HVDC Hub we did not find such a demonstration in the public available

Box 6: OffshoreGrid (2011) study

The study compares the cost-benefit of two modeling scenarios:

i) a direct offshore grid design which starts with shore to shore standalone investments and then allows combined solution; and

ii) a split offshore grid design which starts connecting wind farm hubs to create interconnection capacity. The study is based on a reference case that assumes that the interconnectors included in the ENTSO-E TYNDP will be implemented by 2020, and 126 GW of offshore wind will be connected by 2030.

The study projects promising net gains in the two scenarios that have been modeled starting from the previously mentioned reference case:

i) would generate benefits (reduction of generation

costs) of €21 bn across a lifetime of 25 years, for a transmission investments cost of €7.4 bn;

ii) would generate benefits of €16 bn across a lifetime of 25 years, for a cost of €5.4 bn.

But, it is not fully clear how sensitive these results are to the assumed generation mix for 2020 and 2030, and the evolution of the technology (e.g., HVDC components availability and costs), etc, which are very uncertain today.

Perhaps the announced study by ENTSO-E will be more conclusive. When announcing to study the economic rationale to go towards combined solutions offshore, ENTSO-E said to expect that there might be opportunities, but mainly after 2020 (ENTSO-E, 2011).

documentation. In the case of the Cobra Cable, there is a study that claims to have demonstrated the economic case of this combined solution, but based on the publicly available documentation it is not possible to check the scientific robustness of this claim (see also Box 6). Furthermore, the economic case of larger scale combined solutions will depend on the development of advanced grid hardware and software, such as HVDC circuit breakers, and HVDC control systems.

3.2 Developing combined solution projects under the current regulatory frames: difficulties and remedies

In this section, we discuss the development of these projects under the current regulatory frames to identify the main difficulties and possible remedies. We subsequently look at the national frames for trans-

mission investments, the national renewable support schemes, the multi-stakeholder setting, the required offshore grid technology development, and the sequential decision process that apply to these projects.

3.2.1 National frames for transmission investments

Not aligned national frames for transmission investments make it difficult for stakeholders to cooperate in the development of combined solutions. For instance in the case of Kriegers Flak, the Danish and German TSOs are responsible for the interconnectors as well as for the connection of offshore wind farms in their waters, while the Swedish TSO is only responsible for interconnectors. In the case of Cobra, the Dutch and Danish TSOs might be able to connect a German offshore wind cheaper than the German TSO, but they are not responsible for it and the

German TSO is obliged to connect. Moray Firth is a national project so that this difficulty does not apply to that project. Moreover, it is not even clear whether combined solutions will be considered as connections or interconnection or both under the current regulatory frames, while in most EU member states who is responsible and who pays depends on the answer to this question.

A promising remedy would be to harmonize the national frames towards the guiding principles of an economically sound regulatory frame for transmission investments (chapter 1 & 2). This is promising because it would imply that the planning responsibilities of TSOs and regulators¹³ would then be more aligned than they are today (first principle). It would also imply having a Community-wide transmission and connection planning for offshore grids, including combined solutions. Competitive tendering would then also be organized for the design and development of the different parts of the combined solutions (second principle). A joint tender could then be organized so that the winner of that tender would internalize the coordinated investment problem. Alternatively, in cases where tenders for combined solutions would be too expensive or cumbersome to organize, third parties (including the offshore wind farm developers) could be allowed to propose combined solutions for a regulated return. Harmonizing into an economically sound regulatory frame would also imply that each offshore wind developer pays for its connection (third principle), so that they would be more cooperative in developing combined solutions to reduce the cost of their connection.

Note finally that besides not aligned stakeholder re-

13. Note that when we mention TSO involvement to implement the principles in the above paragraphs, this of course also implies each time that this involvement is regulated by the National Regulatory Authority; cooperation among TSOs then also requires cooperation among NRAs. It should not be that some TSOs would be regulated by governments offshore.

sponsibilities, also other rules and procedures can create distortions that need to be addressed. For instance, this is the case for the rules defining the priority of connection and dispatch, the balancing charges and how offshore wind farms have to support balancing costs, etc. (see for instance E-Bridge, 2010).

3.2.2 National renewable support schemes

Not aligned national renewable support schemes for offshore wind farms also make it difficult for stakeholders to cooperate in the development of combined solutions. For instance in the case of Kriegers Flak, this is not necessarily an issue, but the current project design only integrates three national solutions, whereby each country continues to import the offshore wind produced in its waters, which is not necessarily the best design. In the Cobra case, the envisaged combined solution would imply that German offshore wind could feed into the Danish or Dutch system, rather than the German system, while the Germany renewable energy support is solely for energy delivered into the German system, and the German TSO is responsible for marketing this energy. Moray Firth is a national project so that this difficulty does not apply to that project.

Therefore, as elaborated below, a promising remedy would be to harmonize renewable support schemes for offshore wind farms, or at least to improve their compatibility.¹⁴

3.2.3 Multi-stakeholder setting

Even if the regulatory frames and renewable support schemes would be harmonized, the development of combined solutions still requires cooperation between several stakeholders that do not necessarily

14. See the ongoing CEER (2011) public consultation on the incompatibility issues of national renewable support schemes.

benefit from this solution. For instance in the case of Kriegers Flak, three TSOs, three wind developers and three national regulatory authorities are involved. In the case of Cobra, this will be at least two TSOs and two regulators, and potentially several wind developers. Moray Firth involves only one TSO and regulator, but potentially several wind developers. This multi-stakeholder setting is problematic because the distribution of benefits of offshore infrastructure is dispersed between many countries and between generators and consumers, with winners and losers that might need to be compensated. As studied in Egerer et al. (2011), this is especially the case for combined solutions.

A promising remedy (see below) would therefore be the facilitation of the ex-ante allocation of the costs and benefits of the investment (chapter 1). This will be necessary to implement the beneficiaries pay principle for combined solutions, correcting the asymmetry between costs and benefits of the stakeholders involved in developing these projects.

3.2.4 Offshore grid technology development

The dependency on offshore grid technology development further complicates combined solution projects because this development is hampered by the typical market failures that apply to RD&D (see THINK, 2011a).

For instance, the technology to use in combined solutions would typically be HVDC VSC, which is relatively new technology that has already been used for standalone lines, but not yet in a combined solution. As mentioned previously, the combined solution systems require more advanced hardware and software that still need to be developed and tested.

Therefore, as elaborated below, a promising remedy

for the required offshore grid technology development would then be to coordinate and speed-up their development.

3.2.5 Sequential decision process

A final complication is that all the above difficulties have to be overcome in a context of uncertainty and irreversibility, while combined solutions are typically phased grid developments.

For instance in the case of Kriegers Flak, the complete international solution with all offshore wind turbines spinning, all modules of the grid connection in operation, and electricity being traded, is still some years in the future, while the first building blocks and the most important decisions to enable a combined solution are not that far away. The dimension of the offshore platform for the first wind farm, which is a significant cost factor in the total project, is referred to as one of these early decisions that precondition later developments as it would need to be oversized to be able to add equipment later.

Besides the dimensions of offshore platforms, the irreversibility and incompatibility issues between HVDC technologies also include the cost of switching from CSC to VSC HVDC technology, the cost of combining HVDC systems that operate at a different voltage, the cost of retrofitting a converter station to make it multi-terminal, and possible costs caused by the incompatibility of components coming from different manufacturers.

Therefore, as more elaborated below, a promising remedy could hence be to do more than only include offshore grid development in a Community-wide connection and transmission plan (see section 3.2.1). We also need to develop new transmission planning methods, for instance to capture the value of invest-

Box 7: Summarizing the assessment of which difficulties apply to which of the combined solution project

Note that, considering the below table, it is not surprising that for instance in the case of Kriegers Flak, the initial project ambition has already been reduced: the Swedish TSO left the project (though being allowed to anyway step into the join solution at a later

stage), the German TSO could not wait with pursuing a standalone solution for one of its offshore wind farms, and the Danish offshore wind development has been downscaled (Meeus and Saguan, 2011).

Difficulty	Kriegers Flak	Cobra	Moray Firth
Misaligned national frames for transmission investments	Red	Red	Green
Misaligned national renewable support schemes	Yellow	Red	Green
Multi-stakeholder setting	Red	Red	Yellow
Offshore grid technology development	Red	Red	Red
Sequential decision process	Red	Red	Red

ing today to create more options for possible incremental offshore grid investments.

To sum up, combined solutions face tremendous difficulties under the current regulatory frames. As summarized in Box 7, the three projects we analyzed are confronted with most if not with all of these difficulties. With these frames, the offshore grid development will be distorted towards a multiplication of standalone lines, even in cases where there would be clear economic case for combined solutions. However, we also identified remedies, which include: 1// harmonizing into economically sound regulatory frames for transmission investments; 2// harmonizing the renewable support schemes for offshore wind farms; 3// facilitating the required ex-ante investment cost benefit allocation; 4// speed-up offshore grid technology development; 5// adapt the Community-wide transmission planning to offshore grids.

3.3 Possible role for the EU

In this section, we consider two types of EU intervention to improve the currently mainly national regulatory frames for combined solutions, i.e. what we will refer to as a soft versus a stronger type of EU intervention. The soft type of EU intervention creates EU added value by guiding and supporting the ongoing experimentation with novel regulatory frames at the national and regional level. The stronger type of EU intervention is then about strengthening the EU regulatory frame for combined solutions.

For each of the remedies presented in the previous section, we consider in what follows whether it is enough to have a soft type of EU intervention, or whether the strong economic features (i.e. network externalities, cost and technology uncertainties, and economies of scale) of the investments demand a stronger EU intervention. Following the subsidiarity

principle, the second type of EU intervention can indeed only be justified if the first type of EU intervention would be problematic.

3.3.1 Harmonizing into economically sound regulatory frames for offshore transmission investments

To harmonize into economically sound regulatory frames for transmission investments, the first type of EU involvement would imply to do that on a voluntary basis. This is typically done by adopting indicative guidelines at EU level. These guidelines could then encourage member states to fine-tune their regulatory frames according to the guiding principles of an economically sound frame, i.e. planning principle, competition principle, and beneficiaries pay principle (chapter 1 and 2). Regional Initiatives supported by the EU level is another commonly used approach to promote voluntary harmonization.

Contrarily, the second type of EU involvement would imply to impose legally binding guidelines right away. Then, the EU could gradually enforce a EU level target model for the regulatory framework applied to transmission investments.

Due to the strong cost and technology uncertainties of combined solution projects, their economic case is still uncertain, especially for larger scale projects. This implies that harmonization is currently mainly required regionally. For instance, it is not really necessary to already harmonize the frames of the North Seas countries in the same way as the Mediterranean Sea countries. Moreover, experimentation with novel regulatory frames at the national level has only just started so a strong EU intervention risks to prematurely stop the regulatory process of investigation and discovery of what works and what not. Therefore, the soft type of EU intervention that guides and supports

regionalized solutions seems to be the most appropriate approach for the implementation of this remedy.

3.3.2 Harmonizing the renewable support schemes for offshore wind farms

A soft intervention at the EU level to prompt the harmonization of the renewable support schemes would be to promote the voluntary use of existing flexibility mechanisms (i.e. joint project and joint support scheme mechanisms) for offshore wind farms. This would help to reduce the distortions coming from the national schemes (EU, 2009; Klessmann et al., 2010; Ahner, 2011; Ragwitz, 2010; CEER, 2011). Indeed, the joint project mechanism, e.g., allows member states to deviate from their default renewable energy support scheme, and to cooperate to give tailor made support to a project.¹⁵ Differently, the joint support scheme mechanism allows member states to join or coordinate their national support schemes, which requires a stronger commitment from the countries involved.

An implementation of the second type of EU involvement would be to harmonize renewable support schemes at EU level, which could include the introduction of an EU support scheme. Such intervention has been frequently discussed as a promising action; however, it has proven to be controversial both academically and politically (THINK, 2011b).

Due to the regional scope of current combined solutions projects, the same rationale applies as in the previous section. A harmonization at national or regional level (depending on the projects) not only gives an opportunity to regulatory experimentation at

15. For instance in the case of Kriegers Flak, it would imply that the Danish, Swedish, and German wind farms in that area could be developed as a single renewable energy project. The support could be allocated via tender to a developer who would then internalize the coordination between the different wind farm developments (see also section 3.3.1).

this level, but also avoids the difficulties of the implementation of a EU-wide support scheme. Therefore, the soft type of EU intervention to support regionalized solutions seems to be also the most appropriate approach for the implementation of this remedy for combined solutions.

3.3.3 Facilitating the ex-ante allocation of costs and benefits of offshore transmission investments

The first type of EU involvement to facilitate a proper cost benefit allocation would imply to facilitate regional arrangements for combined solution projects rather than the bilateral agreements that are typically made today for transmission expansion investments across borders, as in the case of NorNed. Then, the evaluation of costs and benefits would also be done regionally, among the different member states involved in the project.

Differently, the second type of EU involvement would imply the design of an EU mechanism for investment cost and benefits allocation, as well as to adopt an EU approach to packaging projects. Packaging is about approving a bundle of projects that individually make sense cost benefit wise, but would result in winners and losers among member states, while in aggregation they avoid that there are losers.

Despite the regional scope of existing combined solution projects, the network externalities and economies of scale of these projects are such that their impact is typically European. Moreover, even for smaller projects with a regional impact, the relevant region can be project dependent, so that the EU approach could include the identification of the relevant region to then partly regionalize the ex-ante investment cost and benefit allocation. Hence, the strong type of EU involvement is advisable for the implementation of

this remedy, keeping in mind that it could be complemented by partly regionalized solutions.

3.3.4 Speeding-up offshore grid technology development

The first type of EU involvement to accelerate the development of offshore grid technology would be to continue to rely on member states to strategically identify the research, development and demonstration activities that are needed and to give them priority, and to provide EU funding to fill the gaps.

A stronger EU intervention is what is already ongoing with the Strategic Energy Technology (SET) Plan, whereby an EU process is introduced to prioritize research, development and demonstration actions for technologies that are considered strategic to achieve the EU policy objectives. This would then imply to include offshore grid development in the SET-Plan, which would result in setting up an industrial initiative that would draft and implement a technology roadmap. The main goal would be to speed-up offshore grid technology development required for large-scale combined solutions (larger than Kriegers Flak, Cobra, and Moray Firth).

Currently, the SET-Plan already has a technology roadmap made by wind manufacturers and another one developed by TSOs (Lemmens, 2010), including some research and demonstration activities on offshore grids (Constantinescu, 2011). However, there is no roadmap performed by HVDC manufacturers, focusing specifically on offshore grid technology development. Such a roadmap could, for instance, facilitate the development of standards to ensure interoperability between components of different manufacturers,¹⁶

16. Note that there is an ongoing discussion at international level regarding HVDC technology standards that could already partly address this issue. For instance, the CIGRE Study Committee B4

which is not probable to happen by only providing grants to specific projects. Moreover, the roadmap would also facilitate a better allocation of EU funding.¹⁷ Therefore a stronger type of EU involvement seems to be the most appropriate approach for the implementation of this remedy.

3.3.5 Adapting the Community-wide transmission planning to offshore grids

A soft EU intervention to adapt transmission planning to offshore grids could be to provide funding for the development of improved transmission planning methods,¹⁸ with indicative guidelines on how to use them in national planning. This would lead to more harmonized planning across member states, as the approaches would slowly converge.

Otherwise, the second type of EU involvement could be implemented by extending the current Community-wide Ten Year Network Development Plan (TYNDP) into a Twenty/Thirty year plan with mandatory use of improved transmission planning methods. The extension of the plan's horizon is very important in the sense that the potential opportunities for combined solutions are mainly beyond 2020, and so are currently not included in the Community-wide transmission planning.

HVDC and power electronics and the CENELEC CLC TC 8X Working Group are working on that.

17. Note that combined solution projects from our overview received EU funding from the European Economic Recovery Program for being first of a kind projects, i.e. Kriegers Flak (grant of 150 M€), Cobra cable (grant of 86.5 M€), Moray Firth HVDC Hub (grant of 86.5 M€) (Figure 6). However, it would have been more opportune to organize a competitive tender for combined solution projects (see THINK, 2011a).

18. The FP7 Call on Electricity Highways (area ENERGY.2012.7.2-1) with the ENTSO-E response to set up a Consortium to work towards a Modular Development Plan on pan-European Electricity Highways System 2050 (MoDPEHS) is a good example of this.

Considering that network externalities and economies of scale of combined solution projects are such that the impact is typically European, it is important to optimize their planning from an EU perspective, instead of optimizing benefits nationally or regionally. Moreover, even if common guidelines could help to harmonize transmission planning methodologies across member states, the prioritization of national welfare would still prevail. Therefore, a stronger EU intervention is recommended to implement this remedy.

4. Recommendations

The analysis in this report shows that the added value of additional EU policy actions for offshore grids depends on whether the offshore grid will develop as a multiplication of standalone lines or whether there will be a transition towards combined solutions. Therefore, we provide recommendations for standalone lines and combined solutions separately in what follows.

4.1 Standalone lines

The current mainly national regulatory frames for offshore transmission investments are economically unsound. However, this does not represent a great challenge from the EU perspective for two reasons: first, unsound farm to shore regulatory frames do not hinder the achievement of the EU objectives; and second, even if the current situation for shore to shore investments can hamper the achievement of EU objectives, the problem is similar to onshore transmission expansion investments. So, for both types of investments, there is no need for a specific EU intervention for offshore grids. Nonetheless, we consider that, regarding standalone lines, it is important to continue the following policy actions that are ongoing for grids, onshore as well as offshore:

1. It is important to continue the implementation of the third package, comprising a Community-wide transmission planning that already includes shore to shore investments. Additionally, it is worth mentioning that this still needs to be backed-up by an EU level facilitation of the ex-ante investment cost and benefit allocation, as proposed by the infrastructure package.
2. It is important to continue the experimentation with novel regulatory frames (e.g. Germany, UK and Sweden) that have been fine-tuned for the connection of offshore wind farms. Note that, even if the currently imperfect fine tuning is not a problem from the EU perspective, the EU could add value by supporting this learning process, for instance, by benchmarking existing practices.

4.2 Combined solutions

From the analysis on combined solutions' projects, it is evident that, without additional EU intervention, future offshore grid developments will be distorted towards a multiplication of standalone lines. Thus, taking into account that small-scale combined solutions (e.g. Kriegers Flak, Cobra, and Moray Firth) can already be opportune today and larger scale solutions might also become opportune in the future, regulatory action is needed.

The least regret EU policy strategy would then be to implement remedies for the tremendous difficulties faced by combined solutions, while also giving a chance to the ongoing regional initiatives. So, where opportune, the EU should opt for a soft intervention, guiding and supporting the national and/or regional policy implementation of the remedies; and, where a regional solution is not viable, a stronger EU involvement is already recommended today. This then leads

to the following recommendations for initiatives to be taken by the European Commission, in addition to the third package and the infrastructure package proposal:

1. **Harmonizing into economically sound regulatory frames for offshore transmission investments:** by providing indicative guidelines that encourage member states to follow the guiding principles of an economically sound regulatory frame (i.e. planning principle, competition principle, and beneficiaries pay principle) to reduce the distortions coming from the national frames (i.e., *soft type of EU involvement, supporting regionalized solutions*).
2. **Harmonizing the renewable support schemes for offshore wind farms:** by promoting the use of the renewable support scheme flexibility mechanisms for offshore wind farms (i.e. joint project and joint support scheme mechanism) to reduce the distortions coming from the national schemes (i.e., *soft type of EU involvement, supporting regionalized solutions*).
3. **Facilitating the ex-ante allocation of costs and benefits of offshore transmission investments:** by organizing the approval of transmission investment project packages, complemented with a new mechanism to implement the beneficiaries pay principle for combined solutions (i.e., *strong type of EU involvement that could be complemented by partly regionalized solutions*).
4. **Speeding-up offshore grid technology development:** through the inclusion of an offshore grid technology roadmap in the SET-Plan, within an industrial initiative driven by HVDC manufacturers, focused on the speed-up of offshore grid

technology development required for large scale combined solutions (larger than Kriegers Flak, Cobra, and Moray Firth). (*i.e., strong type of EU involvement*).

- 5. Adapting the Community-wide transmission planning to offshore grids:** by developing improved transmission planning methodologies and applying them to elaborate a Twenty or Thirty Year Network Development Plan that considers combined solutions (*i.e., strong type of EU involvement*).

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Annexes

Annex 1: Overview of offshore grid visions

Main sources: Electa (2011) and own analysis

Vision	Entity responsible	Geographical scope	HVDC grid scope	Main references
Super-Grid for renewable energies	PhD thesis by Dr. Gregor Czisch	EUMENA countries	Mainly onshore	http://www.transnational-renewables.org/Index.html
DESERTEC	Desertec foundation	EUMENA countries	Onshore and Offshore	http://www.desertec.org Desertec Foundation (2009), Clean power from deserts – The DESERTEC Concept for energy, water and climate security.
Meshed offshore network	Tradewind (IEE project led by EWEA)	EU-27 (including the synchronous zones of UCTE, Nordel, GB and Ireland)	Onshore and Offshore (only in Nordic and Baltic seas)	http://www.trade-wind.eu/ TradeWind (2010), Integrating wind – Developing Europe's power market for the large-scale integration of wind power.
Power Cluster	Partly funded by Interreg IVB, North Sea Region Programme	North Sea Region	Offshore	http://www.power-cluster.net/
Offshore Grid	Offshore Grid (led by 3E)	Baltic and North Sea Region English Channel and Irish Sea Mediterranean region	Offshore	http://www.offshoregrid.eu/ Offshore Grid (2010), Sintef, 3E and Senergy. D8.1 - Final report
Super Smart Grid	European Climate Forum	Europe and North Africa	Onshore and offshore (only HVDC grids)	http://www.supersmartgrid.net A. Battaglini, J. Lilliestam, C. Bals, and A. Haas, (2008), The supersmart grid. SuperSmart Grid, (2010). 100% renewable electricity – A roadmap to 2050 for Europe and North Africa.
Supergrid	Airtricity	North Sea (UK, Germany and the Netherlands)	Offshore	O'Connor, E., Airtricity, "Common EU Wide Policies for Offshore Wind Energy", presentation at the EWEA-3E Conference
Supergrid and Supernodes	Mainstream Renewable Power	North Western Europe and Mediterranean	Offshore	http://www.mainstreamrp.com/supergrid/
Transnational Offshore Grid	Statnett	Sea around Norway (North Sea/ Northern Europe)	Onshore and offshore	Statnett, (2008). Grid Development Plan for the Main Grid, Presentation

Europagrid	Imera	Mainly North Sea and West from UK	Offshore	http://imeria.ie/imeralimited/Imera_Ltd.html , formerly http://www.imperapower.com
Ocean Grids	Kema	Europe	Offshore	Vaessen, P., KEMA. Ocean Grids around Europe, Presentation, February 13, 2009
North Sea Offshore grid	Greenpeace (led by 3E)	North Sea region	Offshore	Woyte, J. De Decker, and T. Vu Van, (2008). A North Sea electricity grid [R]evolution – Electricity output of interconnected offshore wind power: a vision of offshore wind power integration, Greenpeace – 3E
Supergrid	Greenpeace and EREC	Europe and North Africa	Onshore and offshore	Greenpeace and European Renewable Energy Council, (2009). [R]enewables 24/7: Infrastructure to save the climate Greenpeace (2011). Battle of the grids: How Europe can go 100% renewable and phase out dirty energy
Offshore Grid	EWEA	-	Offshore	EWEA, (2010). Powering Europe: wind energy and the electricity grid
Supergrid – Phase 1	Friends of the Supergrid	North Sea and Germany	Offshore (only an onshore link to Munich)	
The energy report	WWF	All world	Onshore and offshore	WWF (2011). The energy report: 100% renewable energy by 2050
2050 Roadmap	Energy Climate Foundation	OECD Europe	Onshore and offshore	ECF (2010). 2050 Roadmap: Volume 3

Annex 2: Economic and technology features of offshore infrastructures

Main sources: This annex is based on ABB (2011), Alegria et al (2009), Beerten et al. (2010), Beerten et al. (2011), Buijs et al (2011), Cole and Belmans (2009), Belmans (2010), Cigre (2010), Europacable (2011), Ergun et al. (2011), Green and Vasilakos (2011), Hertem and Ghandhari (2010), Lumberras and Ramos (2010a, 2010b), National Grid (2010b), RealiseGrid (2010).

A2.1: Offshore transmission systems

There are three main technological alternatives that can be used for offshore electricity transmission, namely:

- **High Voltage Alternating Current (HVAC)** transmission systems that are commonly used in onshore transmission grids, and also offshore to connect offshore wind farms to shore

- **Current Source Converter High Voltage Direct Current (CSC HVDC)** transmission systems, also called as conventional HVDC, that have been used for offshore interconnectors since the 1950s;
- **Voltage Source Converter High Voltage Direct Current (VSC HVDC)** transmission systems are relatively new that started to be used in the late 1990s.¹⁹

Figure A2.1 is a simplified comparison of the two systems, distinguishing between the required substations and cabling.

- **First observation** is that HVDC systems require a larger substation than HVAC systems because the existing grid to which they connect is based on Alternating Current (AC), so that they need to convert AC into Direct Current (DC), and then convert this DC back into AC at the end of the cable.
- **Second observation** is that HVDC VSC require smaller substations than HVDC CSC systems because the converter stations have a smaller foot-

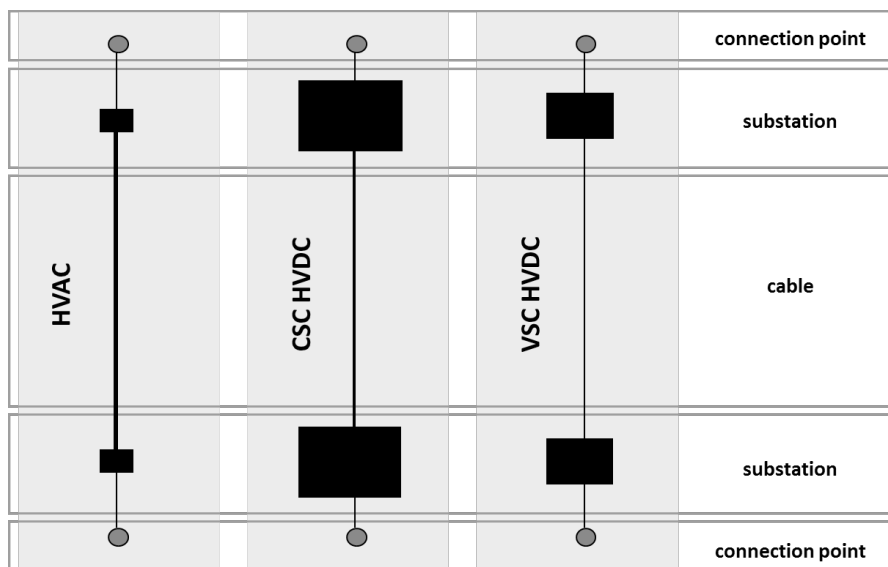


Figure A2.1 – Schematic representation of different transmission systems

19. Indeed, there are only two manufacturers that offer these systems nowadays: ABB (HVDC light) and Siemens (HVDC plus).

Table A2.2 – Suitability of different transmission systems for the types of standalone investments

		HVAC	CSC HVDC	VSC HVDC
Farm to shore	Short distance	Most suitable option	Large footprint of converter stations not suitable for offshore	Can be more suitable in specific cases
	Long distance	Limited cable length	Large footprint of converter stations not suitable for offshore	Most suitable option
Shore to shore	Short distance	Most suitable option within a synchronous zone	Most suitable option between synchronous zone	Can be more suitable in specific cases
	Long Distance	Limited cable length	Most suitable option	Can be more suitable in specific cases

print, e.g. the typical dimensions of a 1000 MW CSC converter station located onshore are of the order of 200m x 175m x 22m while this is only 90m x 54m x 24m for a VSC converter station of the same scale, i.e. an installation that is larger than two football fields versus a barn size installation.

- **Third observation** is that HVAC systems require more cable (due to the high capacitance of the cables) than the HVDC systems, and VSC HVDC requires less cabling than CSC HVDC systems.

A2.2: Offshore transmission connections

Table A2.2 summarizes the suitability of different transmission systems for the types of standalone investments. Note that especially VSC HVDC is a relatively new technology so that the below table is based on today’s relative costs, which can change as these technologies develop.

- **The first observation** is that CSC HVDC systems are not suitable for farm to shore investments because the footprint of the converter stations is too large. HVAC systems are the most suitable option for short distance farm to shore investments because they typically are the cheapest solution, even though VSC HVDC can be more suitable in specific cases where some of the technical advantages of these systems over HVAC matter. HVAC systems are however not suitable for long distance farm to shore investments due to the limited cable length of AC systems, a limitation that does not apply to VSC HVDC so that for longer distances this transmission system becomes the most suitable option.
- **The second observation** is that HVAC systems are most suitable option for short distance shore to shore investments because they typically are the cheapest solution, but they are not suitable for

longer distances because of the limited cable length of AC systems, and they are also not suitable to be used between different synchronous zones. CSC HVDC is therefore the most suitable system to be used between synchronous zones, and definitely if larger distances are concerned. VSC HVDC systems can be more suitable in specific cases where some of the technical advantages of these systems over HVAC and CSC HVDC matter.

Annex 3: Overview shore to shore standalone lines

Main sources: HVDC list from Cigre with complementary information from TSOs and companies responsible by the construction (ABB, Siemens, etc), ENTSOe map of existing transmission line.

#	Name of the connection	Countries involved	Year commissioned	Distance (km)	Power (MW)	Voltage (kV)	Transmission technology
1	Konti-Skan 1	Denmark, Sweden	1964	87	250	250	HVDC CSC
2	Konti-Skan 2	Denmark, Sweden	1988	87	300	285	HVDC CSC
3	SACO1 1	Italy, France	1965	385	300	200	HVDC CSC
4	SACO1 2	Italy, France	1992	385	300	200	HVDC CSC
5	Cross-Skagerak 1 and 2	Denmark, Norway	1977	130	275	250	HVDC CSC
6	Cross-Skagerak 3	Denmark, Norway	1993	130	500	350	HVDC CSC
7	Gotland 2	Sweden	1983	93	130	150	HVDC CSC
8	Gotland 3	Sweden	1987	98	130	150	HVDC CSC
9	Cross-Channel (new)	France, UK	1986	72	2000	270	HVDC CSC
10	Fenno-Skan	Finland, Sweden	1989	233	550	400	HVDC CSC
11	Fenno-Skan 2	Finland, Sweden	2011	200	800	500	HVDC CSC
12	Baltic Cable	Germany, Sweden	1994	262	600	450	HVDC CSC
13	Kontek	Denmark, Germany	1996	170	600	400	HVDC CSC
14	SwePol	Poland, Sweden	2000	245	600	450	HVDC CSC
15	Italy - Greece (GRITA)	Greece, Italy	2001	313	500	400	HVDC CSC
16	Moyle	UK	2001	63.5	250	250	HVDC CSC
17	NorNed	Netherlands, Norway	2008	580	700	450	HVDC CSC
18	SAPEI	Italy	2009	440	500	500	HVDC CSC
19	BritNed	Netherlands, UK	2011	260	1000	400	HVDC CSC
20	StoreBalt	Denmark	2010	56	600	400	HVDC CSC
21	Cometa (HVDC)	Spain	2011	247	400	250	HVDC CSC
22	HVDC NordBalt	Lithuania, Sweden	2015	450	700	300	HVDC VSC
23	Estlink	Estonia, Finland	2006	105	350	150	HVDC VSC
24	East-West Interconnector	UK	2012	261	500	200	HVDC VSC
25	Spain-Morocco Interconnector 1	Spain, Morocco	1997	28	700	400	HVAC
26	Spain-Morocco Interconnector 2	Spain, Morocco	2006	28	700	400	HVAC
27	MEA Isle of Man - UK Mainland link	UK	2000	105	65	90	HVAC
28	Mainland Sweden to Bornholm Island, Denmark, Bornholm Cable	Sweden, Denmark	2005	15	60	60	HVAC
29	Nemo	Belgium, UK	2016	150	1000	250	HVDC CSC

Annex 4: Overview farm to shore standalone lines

Main sources: <http://www.lorc.dk/Knowledge/Offshore-renewables-map/Offshore-wind-farms>; and own analysis of official websites offshore wind farms

#	Name of the wind farm	Country	Year commissioned	Distance to shore (km)	Power (MW)	Voltage (kV)	Transmission technology
1	Arklow Bank 1	Ireland	2003	10	25.2	25	MVAC
2	Beatrice	UK	2007	23	10	33	MVAC
3	Blyth	UK	2000	1.6	4	11	MVAC
4	Burbo Bank	UK	2007	6.4	90	33	MVAC
5	Egmond aan Zee	Netherlands	2006	14	108	34	MVAC
6	Hooksiel	Germany	2008	0.4	5	20	MVAC
7	Hywind	Norway	2009	10	2.3	22	MVAC
8	Inner Dowsing	UK	2009	5.9	97.2	33	MVAC
9	Kemi Ajos	Finland	2008	2.6	30	20	MVAC
10	Kentish Flats 1	UK	2005	10.75	90	33	MVAC
11	Lynn	UK	2009	5.9	97.2	33	MVAC
12	Middelgrunden	Denmark	2000	1	40	30	MVAC
13	North Hoyle	UK	2004	7.2	60	33	MVAC
14	Paludans Flak	Denmark	2003	3.5	23	30	MVAC
15	Rhyl Flats	UK	2009	8	90	33	MVAC
16	Scroby Sands	UK	2004	2.3	60	33	MVAC
17	Sprogoe	Denmark	2009	10.6	21	10	MVAC
18	Utgrunden	Sweden	2000	8	10.5	21	MVAC
19	Vindeby	Denmark	1991	2.25	4.95	10	MVAC
20	Yttre Stengrund	Sweden	2001	4	10	20	MVAC
21	Alpha Ventus	Germany	2010	52.5	60	110	HVAC
22	Baltic 1	Germany	2010	16	48.3	150	HVAC
23	Barrow	UK	2008	7.5	90	132	HVAC
24	Belwind	Belgium	2010	46	165	150	HVAC
25	Greater Gabbard	UK	2008	26	504	132	HVAC
26	Gunfleet Sands	UK	2010	7	172.8	132	HVAC
27	Horns Rev 1	Denmark	2002	17	160	150	HVAC
28	Horns Rev 2	Denmark	2009	30	209.3	150	HVAC
29	Lillgrund	Sweden	2007	7	110.4	130	HVAC
30	Nysted 1	Denmark	2003	10.8	165.6	132	HVAC
31	Princess Amalia	Netherlands	2008	23	120	150	HVAC
32	Robin Rigg	UK	2010	8	180	132	HVAC
33	Roedsand 2	Denmark	2010	8.8	207	132	HVAC
34	Thanet	UK	2010	11.4	300	132	HVAC
35	Thornton Bank 1	Belgium	2009	28.7	30	150	HVAC
36	Walney 1	UK	2011	14.4	183.6	132	HVAC
37	Avedore Holme	Denmark	2009	0.05	7.2	-	-

38	Bockstigen	Sweden	1998	3	2.5	-	-
39	Breitling	Germany	2006	0.5	2.5	-	-
40	Ems Emden	Germany	2004	0.6	4.5	-	-
41	Frederikshavn	Denmark	2003	1	7.6	-	-
42	Irene Vorrink	Netherlands	1997	30	16.8	-	-
43	Lely	Netherlands	1994	0.8	2	-	-
44	Pori 1	Finland	2010	1.2	2.3	-	-
45	Roenland	Denmark	2002	0.15	17.2	-	-
46	Tunoe Knob	Denmark	1995	6	5	-	-
47	Vanern	Sweden	2009	7	30	-	-
48	HVDC BorWin 1	Germany	2009	200	400	150	HVDC VSC
49	HVDC BorWin 2	Germany	2012	200	800		HVDC VSC
50	HVDC DolWin 1	Germany	2013	330	800	320	HVDC VSC
51	HVDC HelWin 1	Germany	2013	130	576	380	HVDC VSC
52	HVDC SylWin 1	Germany	2014	205	864		HVDC VSC
53	Tjaereborg	Denmark	2000	4.3	7	9	HVDC VSC

Annex 5: Conclusions of Industrial Council Meeting (based on report version “V0”, Sept. 2011)

Serge Galant

Technofi // Submission date: September 15, 2011

Introduction

The initial title of the draft slide presentation (“Off-shore grids: towards a least regret EU policy”) has been progressively evolving as the meeting got into in-depth discussions. It is proposed to change the title in view of addressing the question summarized below.

The question

The massive deployment of off-shore wind power comes from the reluctance from the general public to deploy on-shore wind generation and the large wind resource available off-shore in many areas of Europe (with an emphasis on the North Sea).

Although there are plans to off-shore install electricity intensive industries (aluminum or steel production), the most attractive use of off-shore wind power remains the transportation towards high consumption areas, where CO₂ free production would match the 2020 European commitments and the foreseen 2050 decarbonised electricity production picture.

The question to be answered by the THINK consortium is therefore:

“Do we need a collective, EU-based vision and tentative transition paths to reach a Transmission Grid suited to deliver off-shore wind power on-shore”?

The answer is probably yes, since:

- It is still a green field with major risk allocation changes so far on many features (distance, legal,

regulatory, tools to plan and operate the interconnected systems, some technology and emergency operation issues for a future meshed DC submarine grid,...)

- It involves several EU MS and others (Norway, African countries)
- The investment coverage raises issues for the next thirty years, including the cost of system innovation required to detail the investments
- Successful solutions may make European industry a world leader (technology manufacturing, planning and operating of a meshed submarine network)

The tentative answer do the question

The positive answer to the above questions comes from several considerations:

- **Major risk allocation changes** need to be address, which have a European dimension, and have not been addressed so far properly:
 - the legal and regulatory framework with power plants possibly located outside the national territorial zones,
 - the development of planning and operation tools of the resulting grid where close interactions and coordination between TSOs will be a must,
 - emergency operations, especially for a submarine, HVDC possibly meshed grid will require both technologies (like circuit breakers) and operational modes that still need intensive testing.
 - Politically, it will involve more interdependence between Member States of EU27, but also between Europe and Norway, Switzerland, but also North African States.

- **The huge investments** to build the transmission grid raises financing questions at a time where Europe tries to find new areas of sustainable growth, and public bodies are short of investment capacities. The financing issues cover innovation, demonstration, industrialisation and deployment costs with different risk profiles,
- **The successful completion of such a transmission grid** would make Europe a world leader:
 - on technology manufacturing grounds,
 - on power system operations.

since dealing with a submarine, large scale, HVDC grid.

Clarity: what is still fuzzy in the first draft study?

A detailed analysis of the differences between on-shore and off-shore transmission grids expansion due to wind power generation must be presented, showing what are the areas of new knowledge that are still needed to complete a full of-shore transmission grid, and the subsequent needs of EU involvement. The time horizon for the proposal of EU involvement must be given with a clear need to go beyond 2020. There is a necessity for a complementary regulatory framework at EU level which bridges the gap between the Third Energy Package and the Renewable Directive.

There are several EU organizations and several EU instruments that can be involved in setting the vision and detailing the transmission paths. For instance:

- **the European Commission** via DG Research (ongoing call for proposals), DG Energy (a new regulatory framework), DG Competition (the relationship between regulated and non-regulated players, the legal implications of several business models), DG Regio (for the funding of infrastructures),
- **the European Parliament** in the construction of Directives,
- **the Council** in setting interdependence rules on a political basis,
- **ACER** in the enforcement of existing and future regulations based on an increased cooperation between national regulations.

Please detail the ones, which are the most important, the involved instruments and the implied governance issues.

Among the transition paths, the split between an ISO model and a TSO model has been mentioned for the off-shore grid.

Finally, EC representatives have underlined several issues, which can be properly addressed when clarifying:

- the proposed transition paths which could lead to long term scenarios with increased coordination between Member States coordinated / interdependent paths must be mentioned,
- there is an “egg and chicken issue” where TSOs expect manufacturers to provide field proven solutions and manufacturers expect TSO to provide detailed specifications and funding to perform development activities. It was suggested to amplify public funding for RD & D projects where TSOs can demonstrate the costs and benefits of innovative critical technology components (the circuit breaker for HVDC meshed lines was mentioned at length). This is another example of public intervention needed at EU level with a first example in an on-going contract entitled TWENTIES.
- the type of governance which must be implemented to perform such large scale RD and D projects
- the role of electricity storage as a future key technology which deserves attention at EU level (for RD and D, regulations and investment policies)

- the needs for interlinking technology development, regulation development and long term coordinated policies.

Completeness: what are the missing topics to be included

There are four main areas of improvement:

- for the technology scope:
 - AC links are also candidates when compared to DC links,
 - Critical technologies for future networks (DC breakers, short circuit current surges),
 - On-shore network reinforcements induced by off-shore power production,
 - Critical bottlenecks in technology manufacturing (for instance cables).
- for the market scope:
 - the Mediterranean grid,
 - the time to market of technologies (taking into account the costs of large scale system demonstrations required before system deployment),
 - standardisation of grid configurations / components
 - interoperability of critical technology components
 - innovative regulatory frameworks based on a learning by doing implementation
 - linking with Report N°1 of THINK (innovation funding)

Coherence

There are some incoherencies (or fuzzy elements) which deserve some attention:

- the tentative transition must indeed take into account the planning of future investments, but also more and more coordinated operations

- the initial question raised (do we need a collective EU-based vision and tentative transition path to reach a Transmission Grid suited to deliver off-shore wind power on-shore?) come from a potential market failure:

- ambitious energy policy at EU level (2020 and 2050) impact everyone in Europe,
- but the interdependence consequences are still minimised if not overlooked,
- there is a potential market failure where the interdependence at transmission level will not be solved unless major investments and changes of operational modes (more coordination) are implemented by 2020 and much before 2050,
- addressing this market failure requires system innovation for the grid for which the costs are not yet covered between 2012 and 2020 (FP8), even if the Third Energy Package has made provisions to use the tariffs for such funding

Annex 6: Conclusions of Project Advisors (based on report version "V1", Oct. 2011)

Nils-Henrik von der Fehr

Professor at Department of Economics, University of Oslo // Submission date: October 30, 2011

My comments are based on the first draft of the report dated October 2011, as presented at the meeting of the Scientific Council in Brussels on October 18-19, 2011.

Introduction

The aim of the report is to formulate policy recommendations for the European Commission (DG Energy) on offshore grids in light of EU energy and environmental objectives. The analysis considers two broad questions: (i) to what extent offshore grids differ from onshore grids and (ii) whether there is a rationale for building grids offshore rather than onshore. The main conclusion is that the EU should adopt what is termed a "least regret policy".

Overall assessment

Overall, the analysis is reasonable and the questions posed are satisfactorily answered. Specifically, the conclusion that offshore grids do not involve qualitatively new issues relative to onshore grids is well taken. Also, there seems to be little need for specific measures to promote offshore grids. In short, offshore elements should be viewed as an integrated part of the electricity transmission grid in Europe and regulated accordingly.

The main problems with the report as it now stands is that the arguments are not always entirely clear and that it contains material that seems to be of little relevance for the issues at hand.

Other comments

While offshore and onshore grids are, from a regulatory point of view, essentially the same, certain offshore grid projects could present regulatory challenges in a particularly acute form, due to their large scale, the use of novel technology and involvement of multiple national jurisdictions.

While this is certainly true, the question is to what extent this is a real problem. For example, the fact that new technology is involved cannot automatically be taken as a sign that there may be a market failure, as the report seems to suggest (p 34).

Furthermore, even if such challenges were real, it is not clear that they could not be handled under current regulations and without the involvement of EU level authorities. Indeed, in the examples considered in the report, it does not become clear whether the success, or lack of such, of these project can be related to characteristics of the current regulatory regime.

Much of the discussion therefore becomes rather general, on the pros and cons of various regulatory regimes for transmission networks. While such a discussion may be of value in itself, the reasoning sometimes becomes rather vague or superficial, such as when the report advocates "more planning" and "more TSO involvement", that "each actor should be properly incentivized" and that "offshore wind farms should pay to some extent for their connection" (p 13). It is also not obvious what "a tailored regulatory frame that is economically sound" (p 23) really is. Indeed, the term "least regret policy" remains something of a mystery.

Also, the analytical method applied, which tends to see different aspects of the regulatory regime in isolation, makes it difficult to evaluate the totality of dif-

ferent regulatory regimes; in particular, an apparent weakness along one dimension may be counteracted by strengths along other dimensions. The usefulness of comparisons such as those in Box 3 is therefore somewhat doubtful.

In Section 3.1, the report presents various scenarios for the future of the European transmission grid. Some of these scenarios are, at best, hypothetical and speculative, based on wishful thinking and seem to provide little insight into the real challenges and likely development of the European electricity industry. This material could be cut, or at least substantially reduced.

Dörte Fouquet

Lawyer, Partner at Becker Büttner Held // Submission date: October 30, 2011

General comments

The report on offshore grids is a good start and shows quite some effort.

However, the text needs to be updated regarding recently published studies discussing offshore grids, including the latest “Offshore Grids” study (October 2011) and the “Plan N”. (The report cites to the 2010 version of the Offshore Grids study). Also, closer attention should be paid to the National Renewable Energy Action Plans.

Overall, the report could be more precise and could provide more contexts. Often for example, it is referred to “Member States”, but without indicating which Member States or mentioning examples, or explanations are lacking where they would be needed to support a debatable statement (e.g. that „non-harmonized national frames are a problem“ from EU internal market perspective).

Conceptual comments:

The concept of “least regret policy” needs more explanations. As this is the central point of the paper, it should be clearly defined what is meant from the very beginning. This should be done in the introduction, when the objective of the report is mentioned. It would make sense to explain what is at stake, why a change is needed and what is aimed for with the development of a “least regret policy”.

Then the discussion of (priority) access and transmission rights for renewable energies needs to be corrected and improved. One should consider explaining the concepts first and how they fit into the context of the Renewable Energy Directive 2009/28/EC rather than first mentioning them under the label of “implicit subsidy”. The report seems to suggest that a system in which renewable energy producers do not have to pay connection and transmission costs is not to be preferred and in particular the German system is blamed for “socializing costs”. However, there is insufficient context provided and the argumentation on this point seems rather one-sided and even a bit judgmental. Explanations of the benefits of such a system or of the reasons behind (e.g. how it fits into the German system) it would improve the quality of the argumentation either way.

Then the case studies are flawed by comparing a national project with international projects. Certainly, administration in only one country is easier than in several different Member States. Also, they appear quite incomplete, as not for all cases the same information is given. More information should be provided on each of them and it should be organized in a more structured way, so that the reader can easily compare them and understand the evaluation conclusions.

The use of the “smileys” - and in addition to the fact that the table is incorrect due to the comparison of a national project – should be reconsidered. There are preferable ways of presenting results which allow for better differentiation and are thus closer to the facts.

Comments on content:

The offshore targets mentioned in the introduction are very imprecise, ranging from 2 to 15% of the total generation capacity by 2050. This could be narrowed so as to better reflect recent Member States’ estimates, such as by the German Federal Ministry for the Environment.

Further, the section on the impact of grid extension on the cost of renewable electricity should be more detailed to complete the picture. The one paragraph with reference to another work seems insufficient on this important point.

Also, the assessment of the regulatory framework lacks consideration of the Renewable Energy Directive 2009/28/EC. One could consider including recent European Commission proposals, e.g. the Infrastructure Package, as well.

Annex 7: Conclusions of Public Consultation (based on report version “V2”, Nov. 2011)²⁰

Background

First and foremost, the report must recall that, so far, an off-shore grid and the associated wind farms are not developed based on pure, free market criteria: they involve subsidies and site choices which are proposed by national public authorities. In the end, a connection between a wind farm and the on-shore grid is therefore paid for with the help of subsidies. As long as subsidy schemes across Europe are not harmonized, there is no need for a European-wide guideline to connect an off-shore grid project.

Secondly, only TSOs are allowed collecting income from interconnectors according to the European legislation (EC Regulation 714/2009). Therefore, planning and operation of off-shore grids remain by definition a TSO task. The design of off-shore grids should involve socio-economic criteria in order to avoid underinvestment in grid expansions. This exclude generators; they do not have the right incentives to ensure a socio-economic efficient expansion of interconnectors and off-shore grids.

Thirdly, competition in the construction of off-shore grids is based on tendering processes. Assuming that the design of off-shore grids is performed according to socio-economic optima, and that the construction phase performed cost efficiently using a tender process, European TSOs are then able to design and operate any off-shore grid project in a way that ensures a socio-economic benefit from off-shore grid projects.

Fourthly, the location of off-shore wind farms is based on governmental analysis and TSO planning,

since the need to disperse wind farms geographically within a country comes from the necessity of balancing wind power production. The planning of off-shore grids connected to wind farms should be addressed centrally in order to ensure coordination with any other grid development projects. The location of off-shore grids, closely linked with the location of off-shore wind farms, should be addressed centrally in order to ensure that the overall onshore grid is capable of transporting power flows from the off-shore grid. In the end, off-shore grids will become an integral part of the European transmission grid, going beyond the use of national regulations for ownership, cost allocation, construction and operations.

Last but not least, off-shore grid will require very sophisticated control techniques, since operated as a meshed network, and of course assuming that the chosen grid architectures are in the end controllable. The safe operations of the meshed off-shore HVDC lies then require DC HV switchgears, bearing in mind that grid failure problems in DC grids have an impact on the whole grid, even if such breakers are implemented in the DC part of the grid. Such a technology is yet to be demonstrated at full scale, together with the introduction of more sophisticated coordination tools between TSOs.

Technology availability

There is evidence that technology uncertainty feeds into higher investments costs for grids. Yet, more emphasis should be given on the impact of future electricity demand upon the speed of technological development, since technology manufacturers²¹ very often claim that they can deliver appropriate solutions if they are confident about future orders. This is why early system demonstrations are of use to anticipate on validation steps which precedes early commer-

20. With written comments either in the initial draft report or in a specific paper coming from Commillas, E3G, Energinet, Europacable, EWEA and RWE

21. See for instance background information on HVDC cables: http://www.europacable.com/images/Document_Uploads/Introduction_to_HVDC_Underground_Cables_October_2011.pdf

cial deployment. The report recommends for competitive tenders prior to demonstration projects should be accompanied with higher priority stings for offshore grid projects within the proposed regulation on infrastructure priorities (and associated support from the Connecting Europe Facility).

Moreover off-shore grid will require very sophisticated control techniques, since operated as a meshed network. It requires DC HV switchgears, bearing in mind that grid failure problems in DC grids have an impact on the whole grid without such breakers.

Harmonization issues

The complete harmonisation of either connection regimes or renewable support mechanisms may, on paper, appear to be the most efficient solution to many of the identified problems. Yet, recent evidence shows that proposals for full harmonisation of policies are inevitably politically contentious, requiring considerable more time and efforts to succeed. Political uncertainty on regulatory regimes will then inevitably impact investment processes. It is to manage this risk that “second best” solutions which may be more easily achieved should be addressed and implemented, alongside the parallel process in charge of reaching recommendations on harmonisation.

Locational signals and connection charges

Even though locational signals for offshore generation (offshore generators paying for their connection, while being protected from the risk of poor grid availability) may lead to market efficiencies, there is a significant risk that poorly-designed locational signals could undermine or distort offshore wind development rather than making it more efficient (for instance, placing too much of the cost and risk burden on early investors when new sectors for offshore wind open up). Future emphasis should be put upon the potential risks of poorly-designed charging ar-

rangements, whereas alternative mechanisms could be analysed to ensure offshore wind development in clusters or hubs (e.g. licensing and maritime spatial planning arrangements).

Uncertainty and risk management for off-shore grid development

The THINK report addresses many of the uncertainties that will prevail in the development of off-shore grids. Yet, more emphasis ought to be put on the related risk management issues. It is not only a question of avoiding stranded assets: further consideration should be put on how investments open up or close down future energy system options in the context of decarbonisation. Such options must be valued when developing the appropriate regulatory regimes which will be designed to favour anticipatory investments.

Towards timely investments in off-shore grids

There is technology and economic evidence that off shore wind development will heavily rely on VSC-HVDC technologies. This is not yet an “off-the-shelf” technology. There is a need to start the construction of off-shore grids very early in order to meet high level political goals. This means that, most probably, consumers will have to carry the burden of a larger stranding risk in order to benefit from a long term greener future. Ideally, TSOs should then be pushed by regulation to make a predictive, holistic planning: when audited by a well-informed regulator, this should result in a leaner, faster and more efficient process than stakeholder consultations and compromises.

EWEA response to public consultation of “Offshore grids: towards a least regret EU policy” report

EWEA welcomes the report “Offshore grids: towards a least regret EU policy” prepared by the THINK Consortium. Given the ambitious EU targets on renewable energy penetration, GHG emissions reduction and the creation of a single electricity market, EWEA sees this report as an important assessment of the current regulatory framework for this technology that provides sound policy recommendations for DG Energy.

EWEA believes that wind power is a key enabler for the accomplishment of EU targets. In this sense, we see electricity infrastructure development as a prerequisite of successful market integration. For offshore wind power, this is more evident as infrastructure has to be built from scratch. EWEA believes this represents an opportunity for policy makers to act proactively in shaping the development of a transnational offshore grid to maximise its benefits and we broadly subscribe to the report’s recommendations.


EWEA considers that the [OffshoreGrid](#) project has demonstrated the techno-economic benefits of integrated offshore grid solutions over individual developments. We recognise that there are several visions on how offshore grids could develop. Consequently we agree with the recommendation that greater political coordination is required in the development of a common vision.

We also agree that some questions require a European approach, while others can be better answered at national, bilateral or regional level. Nevertheless, these must be coordinated in order to converge in the achievement of the objectives that the EU and MS have subscribed to. A clear stable policy, regulatory and market framework is required in which division of responsibilities and accountability are clarified.

Specifically with regards to the recommendations on farm-to-shore and shore-to-shore connections, EWEA broadly agrees that regulatory and economic issues need to be tackled for onshore and offshore projects as a whole. No intervention at EU-level is required for specific offshore projects of this type, but solutions should be assessed with common cost-benefit methodology for allocation of costs with cross-border impacts.

EWEA agrees that developing combined offshore grid solutions requires a more regional coordination approach for planning, connection regimes and support mechanisms.

EWEA has repetitively called for offshore grids planning as a high-level priority in the development of EU electricity infrastructure. Therefore, EWEA has welcomed that the EC has highlighted the Northern Seas Offshore Grid as a priority corridor in the recent Infrastructure Package published on 19 October 2011. EWEA believes this is the first step to facilitate coordinated and therefore more cost-effective connection regimes and encourage the development of a common vision as per THINK’s recommendations. Offshore grids subsequently have to be reflected in ENTSO-E development plans, in particular in the upcoming 10-year network development plan.



On the other hand, support for offshore wind energy should be made compatible with combined solutions, the [OffshoreGrid](#) report highlights, however, that to achieve this goal it is not necessary to harmonise European support schemes, but to make them compatible with one another. In this sense, we do not agree with THINK's recommendation for harmonisation of offshore support schemes. We believe that when benefits from an international interconnection are present, bilateral arrangements, adaptations or exemptions to the national support schemes should be examined first.

Finally, EWEA agrees that it is absolutely necessary to maintain technology development and research support until offshore wind energy can be considered a mature and proven technology.

ENTSO-E response to the public consultation on the THINK-report

Topic 5: Offshore Grids towards a least regret policy

1. General Comments

ENTSO-E welcomes the opportunity to comment on the THINK-report “Offshore Grids: towards a least regret policy”. The report covers a number of important areas in which ENTSO-E and our members are currently involved. As such, we are pleased to provide our views on the issues raised by the report. Comments on the document have been provided from a TSO expert perspective and any views expressed should not be considered as a formal ENTSO-E position.

At the outset we would like to stress that it is imperative for Europe’s TSOs to be at the heart of the design, ownership and operation of transmission networks – be they on- or offshore (indeed we would counsel against considering offshore grids in isolation). Developing the transmission infrastructure which Europe needs to achieve challenging and legally binding targets for renewable connections, while ensuring security of supply and ensuring competitive prices, in our view, requires holistic and joined up solutions which only TSOs are capable of providing.

We note that many of the issues raised in the document have much in common with issues raised by the report on transmission tariffs under THINK topic 6. We have responded to that document separately and our responses should be read in parallel. ENTSO-E looks forward to continuing to play a leading role in discussions on this topic and would be pleased to provide additional information if it would prove useful.

2. Farm to shore standalone lines

Who decides and who pays

In respect of farm to shore lines, the report distinguishes between “who decides” and “who pays”. Regarding, the question of who decides, it asks whether connections should respond to generator demands for capacity or whether some sort of anticipatory approach should be taken by TSOs. ENTSO-E notes the following:

- Offshore and onshore reinforcements cannot be considered in isolation and the TSO needs to be the party identifying the optimal design for the on- and offshore system.
- Making investments ahead of a clearly signalled demand for capacity may create stranded asset risk (i.e. if the generator fails to connect). This risk can be taken by TSOs or customers. Passing the risk to TSOs could prove counterproductive by increasing risk, and hence required return, across the entire asset base. Similarly passing the risk to customers can raise questions of fairness. However, investment clearly needs to be made in a timely manner – which is dependent on effective regulation and streamlined permitting processes – and we consider that regulators and TSOs need to work together to ensure projects are

delivered in a timely manner. There may therefore be a case for incentives which reward timely delivery of infrastructure (and the earlier receipts of the benefits of investment by customers).

In respect of who pays, ENTSO-E notes:

- As noted in our response to the THINK report on tariffs, we support cost-reflective charges for generators, so that the costs of transmission may be considered in decision making
- However, while connection costs pass all the stranded asset risk to generators, they can create barriers to entry and first mover advantages, hindering effective competition. Hence the full consequences of such an approach would require careful consideration and we are not convinced that either a fully deep or super shallow approach would be appropriate.
- We do not consider that there are objective reasons to differentiate the approach to charging different types of generation.

Fine tuning regulatory approaches

We are not convinced that the distinction between offshore and onshore projects is entirely appropriate. In our view, there are differences between investment in meshed networks (network deepening investments) and extensions to the network (network expansion investments). The fact that the line is offshore may imply some additional technology risks, though these risks may also exist with onshore projects, such as very high voltage “overlay grid” style developments. However, we agree that the characteristics of offshore projects (and network deepening investments more generally) require focused amendments to regulatory frameworks.

Aside from ensuring that risks are reflected in returns (which we discuss in more detail in the context of cross border projects below) and that investors can be attracted to offshore projects, we consider that elements of regulatory regimes may also need to be updated. Taking steps to adapt transmission charging methodologies and partially reflecting network costs in the charges paid to generators may be beneficial.

Europe is facing a significant need for investment in both generation and transmission capacity. It is important that the overall cost of this investment is minimized and that efficient decisions are made. From a theoretical viewpoint, EU wide locational signals for generators could incentivize investors to consider the impact of an investment on the overall transmission grid. Despite this potential advantage the efforts necessary to design and implement this approach should not be underestimated, and relationships to the location incentive effects of congestion management would need to be considered carefully.

Similarly, we consider that taking steps to remove distortions and supports through regulatory regimes may promote more efficient decision making. It will also be important to recognize that, in some cases and at some point in future, farm to shore connections may be extended to become parts of more meshed solutions. National regulatory regimes need to be capable of dealing with this situation and, as discussed below, in such cases differences between approaches are likely to have more substantial consequences for the efficient functioning of the European electricity market and therefore may need to be proactively addressed.

3. Shore to shore standalone lines

As the report rightly notes, the development of additional cross border capacity is fundamental to completing the internal electricity market and hence promoting the development and delivery of these projects is of particular importance. We consider the following points:

- How to ensure efficient planning
- How to ensure regulatory regimes promote the delivery of such projects.
- The parties which should be responsible for the delivery of the projects.
- Issues around cost allocation.

Efficient planning

ENTSO-E agrees that there is a need to generate information on future offshore developments and a need to plan in a coordinated manner. The ENTSO-E Ten Year Network Development Plan, of which the next release is planned for 2012, will be an important vehicle for identifying required offshore investments. In addition, ENTSO-E has made a proposal to the European Commission to develop a Modular Development Plan of the Electricity Highways System that will consider all timeframes until 2050.

We also note that efficient system planning is dependent on reliable information. We support attempts to improve the quality of information by, for example, requiring proportionate financial contributions from generators or using windows to identify the amounts of capacity to be connected in a given geographic area in order to optimize designs.

Financing and promoting investment

In ENTSO-E's view it is imperative that regulatory regimes do not create disincentives to invest (either nationally or in cross border projects) and are calibrated to focus on the delivery of the outputs which European customers' value and to maximize benefits to those customers. In particular it must be recognized that TSOs compete for investors in a global market place. We consider that creating the conditions to deliver significant volumes of new investment will need a re-think of the regulatory conditions which are applied to TSO's (in particular a move away from a regulatory approach which focuses solely on cost reduction and tariff decreases to an approach which incentivizes efficient and timely investment) and a recognition, and reflection in returns offered by National Regulatory Authorities, of the risks incurred by TSO's when planning and realizing these investments. This is true both on- and offshore and is particularly the case for cross-border investments which are often perceived as carrying more risk and hence are less attractive to shareholders.

In addition, we note the importance of Research and Development expenditure in ensuring that sufficient attention is paid to promoting long term innovation and we welcome proposals to speed up technology development. We also agree that encouraging the development of standards to ensure interoperability between the HVDC components and systems developed by different manufacturers is important. This is an issue which ENTSO-E is currently addressing.

Responsibility for delivery

In ENTSO-E's view, TSOs are the appropriate party to identify a need for cross border investment (and the associated onshore reinforcements that are inevitably also required) and the appropriate party to deliver, own and operate that investment. TSOs are able to take a system wide view and make optimal investments which enhance overall social welfare – leading to significant overall cost savings. This avoids the necessity which merchant interconnector projects face to undersize connections in order to maintain the price difference that makes the project viable and is likely to lead to far more efficient overall solutions. There is a strong track record of successful collaboration between TSOs in developing interconnection projects (and elsewhere) and, in our view, the incremental development of an offshore grid is far more likely to occur under such an approach.

We note that the report proposes competition where possible. We note that TSOs already face strong regulatory incentives to minimize costs (and to demonstrate they have done so) and, in most cases, hold their own tenders for equipment supplies etc (i.e. competition is internalized). We also note that TSOs have considerable experience of negotiating with suppliers which, in highly concentrated markets (such as the market for subsea cables) is of particular importance and can hinder effective competition. We also note that the introduction of competitive regimes can be a time consuming process (circa 9 years in Great Britain) and, at a time when there is a pressing need for investment, we do not consider that such an approach would be proportionate.

Cost allocation

In respect of cost allocation, we would counsel against seeking to apply a 'one size fits all' approach and consider that bilateral/regional negotiation will always have a role to play in finding appropriate solutions. That said, we consider that cost benefit analysis to identify the overall benefit of a project and, perhaps, the expected beneficiaries, could prove a useful first step in this process.

4. Concluding remarks

ENTSO-E hopes that the views contained in this report are useful. We would be pleased to discuss any aspect of the response. We note that ENTSO-E and our member TSOs are closely involved in work in many of the areas raised within the report and we look forward to continuing to contribute positively as work in each area develops.

THINK

THINK is a project funded by the 7th Framework Programme. It provides knowledge support to policy making by the European Commission in the context of the Strategic Energy Technology Plan. The project is organized around a multidisciplinary group of 23 experts from 14 countries covering five dimensions of energy policy: science and technology, market and network economics, regulation, law, and policy implementation. Each semester, the permanent research team based in Florence works on two reports, going through the quality process of the THINK Tank. This includes an Expert Hearing to test the robustness of the work, a discussion meeting with the Scientific Council of the THINK Tank, and a Public Consultation to test the public acceptance of different policy options by involving the broader community.

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