DECC - Research into GB offshore electricity transmission development. Lessons Learned.

FINAL REPORT

- V.2.1
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Sinclair Knight Merz
Victoria House
Southampton Row
London
WC1B 4EA
United Kingdom
Tel: +44 20 7759 2600
Fax: +44 20 7759 2601
Web: www.skmconsulting.com

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1. List of Abbreviations

AC	Alternating Current
DECC	Department of Energy and Climate change
DENA	Deutsche Energie-Agentur GmbH
DOE	Department of Energy
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ENSG	Electricity Networks Strategy Group
GB	Great Britain
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
MEC	Maximum Export Capacity
O&M	Operation and Maintenance
Ofgem	Office of the Gas and Electricity Markets
OFTO	Offshore Transmission Owner
OTCP	Offshore Transmission Coordination Project
OWF	Offshore Wind Farm
SHETL	Scottish Hydro-Electric Transmission Limited
SvK	Svenska Kraftnät
TNUoS	Transmission Network Use of System (tariff)
TAO	Transmission Asset Owner
TCE	The Crown Estate
TII	Transmission Investment Incentives
TSO	Transmission System Operator
TYNDP	Ten Years Network Development Plan

2. Definitions

Coordination	From DECC's tender specification for this project: "Coordination' is taken to mean the sharing and future-proofing, where suitable, of electricity transmission assets back to shore within or between different Crown Estate Round 3 wind farm development zones. It might also involve using such assets for the additional purpose of interconnection between countries. Sharing or future-proofing of assets would be suitable where it led to a more effective or efficient means of meeting DECC decarbonisation and security of supply objectives. This might be the case where coordination resulted in less infrastructure being required, which could reduce costs or planning delays"
Generator	(throughout this report) offshore wind farm developer
Offshore transmission system	A system consisting (wholly or mainly) of the high voltage electric line(s) used for the transmission of electricity between the offshore and onshore substation(s). Hence an offshore transmission system extends from the onshore connection point(s) to the offshore connection point(s). Note that point-to-point connection is also covered under this definition.
National Electricity Transmission System	The system consisting (wholly or mainly) of the high voltage electric line(s) used for the transmission of electricity between substations, power stations, offshore transmission systems or any international interconnections.
Offshore transmission assets	Any hardware, such as plant and apparatus or meters, that constitute the offshore transmission system
Offshore connection point	The point at which the OWF connects to the offshore transmission system. This is the low or medium voltage busbar on the offshore substation platform.
Onshore connection point	The electrical point of connection between an offshore transmission system and an onshore transmission system,

Anticipatory Investment	Anticipatory investment would allow the transmission asset owners to invest, before the need is established through firm commitments of new generation to connect and pay TNUoS charges. Under this arrangement, transmission network companies would make speculative investments in network reinforcements to accommodate growth in renewable generation
Interconnection	AC or DC connection between any two substations
International interconnection	AC or DC connection between the transmission systems of two countries.
Point-to-point connection	A system with a single simultaneous path of power flow from a single generating plant to the load.
Collective connection	A system with a single simultaneous path of power flow from several generating plants to the load.
National Transmission System Operator (TSO)	Entity entrusted to manage the security of the national transmission system in real time and co-ordinate the supply of and demand for electricity, in a manner that avoids fluctuations in frequency or interruptions of supply.
Capacity availability	Availability of export capacity corresponding to 100% of installed capacity.
Energy weighted availability (effective availability)	Availability of necessary export capacity to transfer actual energy production.
Group Processing Approach	Processing of connection applications in batches to allow for minimisation of combined transmission infrastructure required, i.e. where deemed more economically efficient joint connection offers will be made.
Capacity availability	Availability of export transmission capacity corresponding to 100% of installed capacity of an OWF.
Energy weighted availability (effective availability)	Availability of necessary export transmission capacity to transfer actual energy production from an OWF.

3. Introduction

The Government has set an ambitious target for the deployment of renewable energy over the next decade. By 2020, the Government expects that 15 percent of the United Kingdom's (UK) energy needs will be met from renewable sources and suggests around 30 percent of electricity may come from renewables. Offshore wind will play an important part in meeting these renewable energy targets.

The adoption of offshore wind generation has numerous advantages but one of the fundamental issues is the cost of offshore wind farms (OWF) and associated offshore transmission assets.

In addition to existing plans and extensions from Rounds 1 and 2, the Crown Estate (TCE) has tendered the development rights for up to 32,000MW of offshore wind generation under Round 3. In total, there is almost 50,000MW of capacity that is either subject to an agreement to lease (including Scottish Territorial Waters) or has already been leased. To facilitate the expansion of offshore wind, the UK Government has introduced a regulatory regime for offshore electricity transmission which effectively separates the offshore generation from the offshore transmission. Offshore transmission is a licensed activity, regulated by Ofgem (Office of the Gas and Electricity Markets), with the Offshore Transmission Owner (OFTO) licence awarded through a competitive tender process to encourage new participants and funding into the regime. The regime came in to effect in June 2010 with a transition process taking place from June 2009.

Government and Ofgem have consulted extensively on the regulatory regime and competitive tender process. The response to the joint further consultation on the enduring offshore electricity transmission regime in August 2010[1], indicated that while the competitive offshore electricity transmission regulatory regime creates no barriers to coordination, the current incentives may not be sufficient to bring about significant levels of coordination in practice. The Department of Energy and Climate change (DECC) and Ofgem are currently undertaking an Offshore Transmission Coordination Project (OTCP) to consider whether additional measures are required within the competitive offshore electricity transmission regulatory regime to further maximise the opportunities for coordination.

It is within the context of this project that DECC engaged SKM and sub-consultant CEPA to conduct a comparative analysis of offshore electricity transmission regulatory regimes in key

[1] Further consultation on the enduring offshore electricity transmission regime in August 2010 consultation included questions on the proposals for allowing a generator build option, a further opportunity to comment on the detail of the early and late OFTO appointment options, and requests to present views on whether any further actions were necessary within the offshore electricity transmission regulatory regime to facilitate the development of a coordinated onshore and offshore transmission system.

countries with significant amounts of existing (and/or planned) offshore wind generation (GB[2], Germany, Denmark, Netherlands, Ireland, France, Belgium, Sweden, USA[3], China) and articulate lessons learned from other relevant infrastructure sectors. The results of the project are covered in three deliverable reports:

Deliverable 1: A comparative assessment of the GB offshore electricity transmission regulatory regime with the regimes of other key countries.

Deliverable 2: An assessment of key lessons learnt from how other countries deal with coordinated electricity transmission development between the offshore developers.

Deliverable 3: Assessment of key lessons learned (which are relevant for the development of GB offshore electricity transmission systems) from how comparable infrastructure in other relevant sectors, such as oil, gas, and CCS pipelines in the UK and other countries, deal with coordinated infrastructure development between different developers.

This report provides an assessment of key lessons learned from the comparative assessment of the offshore electricity transmission regulatory regimes employed in different countries. The report is structured as follows. First the report introduces two broad types of offshore electricity transmission regulatory regimes that were identified in the Deliverable 1. The definition of "coordination" is also provided to facilitate the discussion of the key lessons learned. Potential coordinated offshore transmission system design options are introduced alongside an explanation of the rationale behind these designs. The discussion of the lessons learned is then structured around these coordinated designs and whether these are likely to be delivered under the two broad offshore electricity transmission regulatory regimes. Broad characteristics of the offshore electricity transmission regulatory regimes, encouraging the delivery of coordinated offshore transmission system designs, are extracted based on the lessons learned. Finally, the main conclusions are presented.

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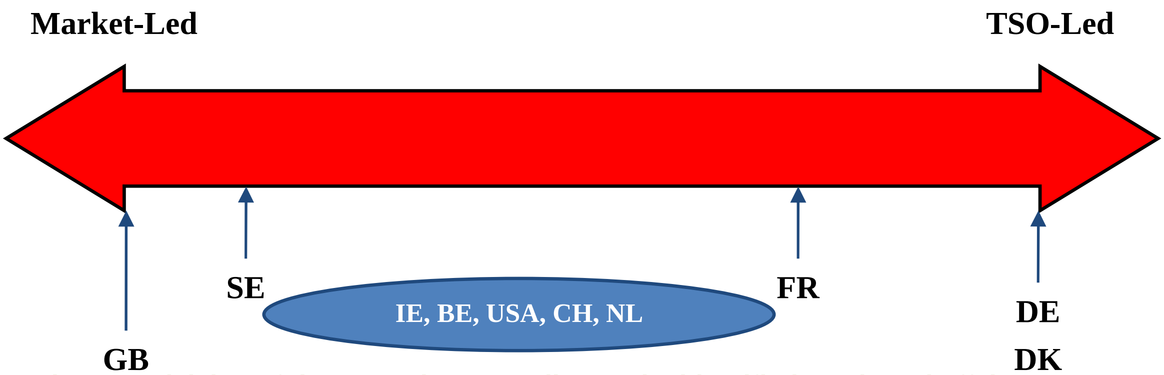
[2] Great Britain (GB)
[3] United States of America (USA)

4. Two offshore transmission infrastructure regimes and characteristics

From the comparative assessment of the offshore electricity transmission regulatory regimes employed in different countries (Deliverable 1), two broad approaches were identified:

- the TSO-led[4] approach where one body (national TSO) is responsible for the design, construction and operation of the entire offshore transmission system; and
- the market-led approach where a separate body is responsible for the offshore transmission system for one or several projects.

The TSO-led approach is employed by Denmark and Germany (and France in the future) where the TSO is responsible for planning, construction and operation of the offshore transmission system. The market-led approach is employed by GB and Sweden[5], and countries with generator built/owned/operated offshore transmission systems like Belgium, Netherlands, Ireland, USA, China (Figure 1).



- **Figure 1 Division of the countries according to the identified two broad offshore transmission approaches.**

The characteristics of these two approaches are summarised in Table 1 and discussed below.

For the TSO-led approach, the national TSO is responsible for planning, designing, funding, constructing and operating the offshore transmission system for an OWF. Transmission system planning is holistic (i.e. includes offshore and onshore transmission systems). The TSO funds the offshore transmission system and wider onshore transmission system reinforcements, where necessary. The generator is required to provide financial security to guarantee this investment. In some cases other forms of guarantee, such as the project status criteria in Germany, are used. The

[4] Transmission system operator (TSO)
[5] Note that in GB and Sweden the offshore transmission and generation are unbundled. However (as opposed to TSO-led approach each project might have its own separate transmission asset owner and operator.

cost of the transmission infrastructure is recovered from the demand customers though the Transmission Network Use of System (TNUoS) tariffs. There are fixed timelines for both the connection process and the construction of the associated transmission infrastructure.

In the market-led approach, a generator or dedicated Transmission Asset Owner (TAO) is responsible for designing, funding, constructing and operating the offshore transmission system for an OWF. The national TSO still has a key design and coordination function in this approach, by making available offshore development studies and information statements to OWF developers or dedicated TAOs. The national TSO funds the connection costs at the onshore connection point (e.g. necessary onshore substation works) and wider onshore transmission system reinforcements, where necessary. The generator is required to provide financial security to guarantee this investment. The costs of the offshore transmission assets are recovered through the TNUoS tariffs, which are levied either on the demand customers or split between the generation and demand. There are set deadlines, by which the TSO must process the connection application, but no set deadlines for construction of the offshore transmission system.

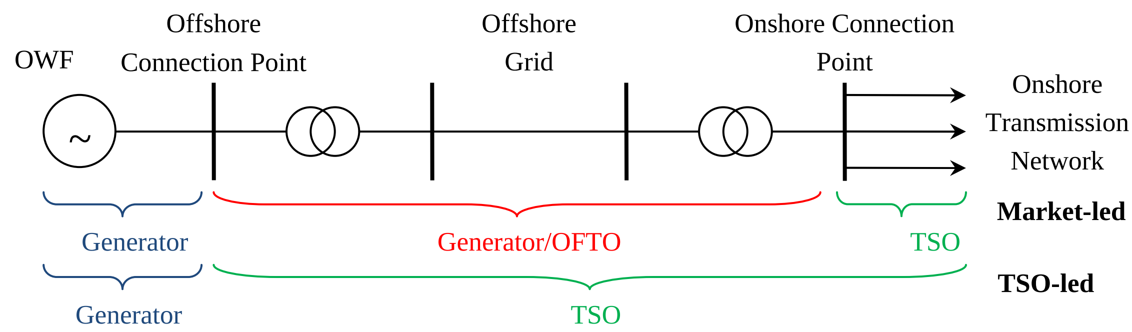
Both of the broad offshore electricity transmission regimes described above can provide for anticipatory onshore transmission system reinforcements but none of these regimes have measures in place for anticipatory investments on the offshore transmission system. In Germany (TSO-led approach) there is a provision for oversized collective connections or even collective connections with maximum technically possible transmission capacity where deemed efficient. In GB (market-led approach) there is provision for some offshore transmission oversizing.

Table 1 Characteristics of two broad offshore transmission regimes: TSO-led and market-led

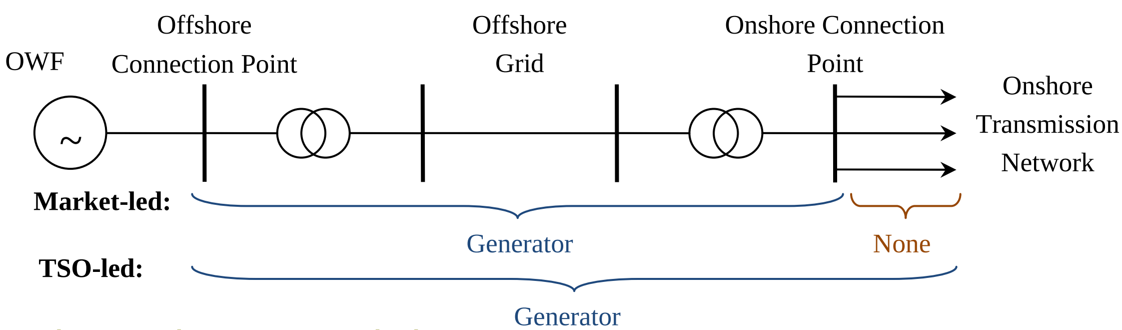
Characteristic	TSO-led	Market-led
Who owns the offshore transmission assets?	TSO	Generator[6]/TAO
Who is responsible for the operation and maintenance (O&M) of the offshore transmission assets?	TSO	Generator/TAO
Is there overall offshore transmission system planning?	Yes as a part of the onshore transmission network development plan	No centralised plan, but studies/information statements as well as one NETSO for onshore and offshore systems
Is there standardisation of offshore transmission assets (standard voltage levels, standard platform/block sizes)?	No standards	No standards
Who constructs the offshore transmission system?	TSO	Generator/TAO
Who initiates the connection process?	Generator	Generator
Are there set timelines for the connection process?	Set timelines for processing of a connection application and construction of the offshore transmission system	Set timelines only for processing of a connection application
Is there shared use of offshore transmission assets between projects?	Possible, under construction[7]	Possible, but doesn't exist yet
Does the regime make provisions for anticipatory investment or oversizing?	Anticipatory reinf. onshore. Oversizing or modular solutions offshore allowing future extensions.	Anticipatory reinf. onshore and none offshore
Who funds the offshore infrastructure?	TSO, Figure 2	Generator/TAO, Figure 2
Who funds the necessary onshore infrastructure	TSO, Figure 2	TSO, Figure 2
Who guarantees the investment?	All Generator, Figure 3	Different parties guarantee different parts of the investment, see Figure 3

[6] Throughout this table “Generator” means OWF developer
[7] In Germany: BorWind 1 and 2 substations to connect BARD Offshore 1, Veja Mate, Global Tech 1 OWFs

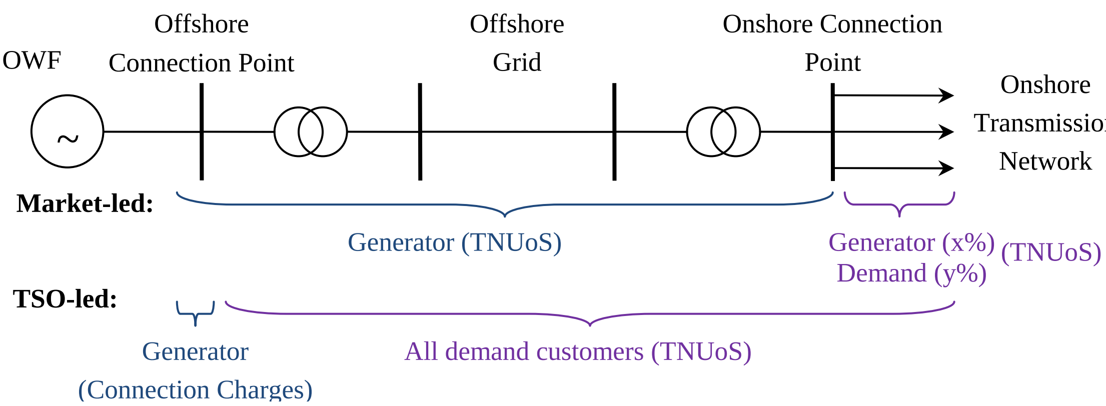
What form of guarantee is required?	Financial or project status criteria	Financial
Who pays connection charges and/or TNUoS?	All paid by demand customers, Figure 4	Different parties pay different parts of the connection charges and/or TNUoS charges, see Figure 4.
Who is responsible for obtaining consent for offshore transmission system?	TSO is responsible	Generator/TAO is responsible
Can additional capacity be consented for undefined future projects?	Oversized platform (in Germany), but not cables.	No



■ **Figure 2 Who funds the transmission infrastructure?**



■ **Figure 3 Who guarantees the investment?**

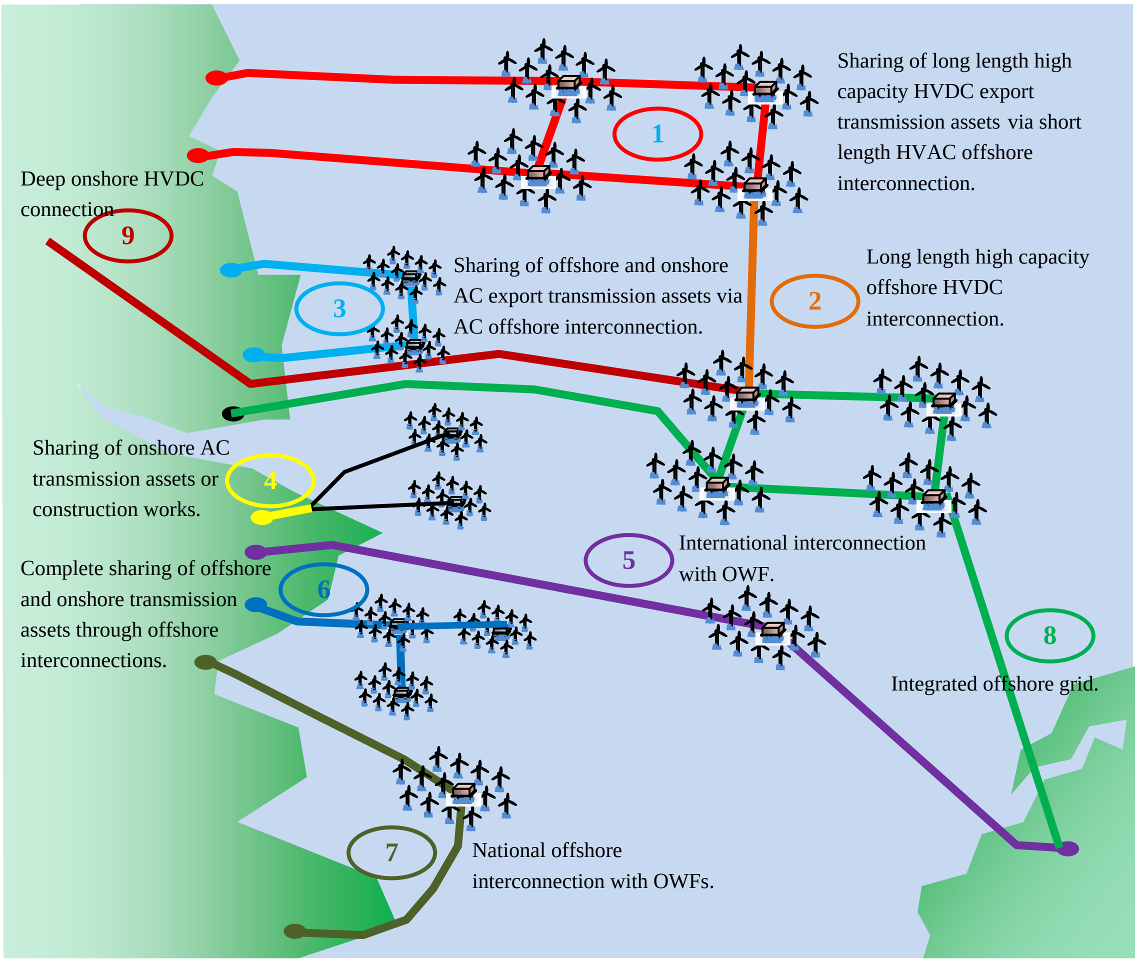


■ **Figure 4 Who pays for the transmission charges?**

5. Coordinated offshore transmission designs

To facilitate the discussion of the key lessons learned, from how other countries deal with the coordinated electricity transmission development between OWFs, it is necessary to define 'coordination' in the context of this project. From DECC's tender specification for this project:

> *'Coordination' is taken to mean the sharing and future-proofing, where suitable, of electricity transmission assets back to shore within or between different Crown Estate Round 3 OWF development zones. It might also involve using such assets for the additional purpose of interconnection between countries. Sharing or future-proofing of assets would be suitable where it led to a more effective or efficient means of meeting DECC decarbonisation and security of supply objectives. This might be the case where coordination resulted in less infrastructure being required, which could reduce costs or planning delays.*



▪ **Figure 5 Coordinated offshore transmission design options**

Figure 5 illustrates potential coordinated offshore transmission system design options in the context of the above definition. Table 2 lists existing examples and proposed projects as well as describes the rationale behind each coordinated design shown in Figure 5. Note that the table is colour coded to match with the coordinated designs illustrated in Figure 5. Table 4 in Appendix A explains stages of the offshore project development where cooperation between the stakeholders involved is required for each of the coordinated designs.

The discussion of lessons learned will be structured around these coordinated designs and whether these are likely to be delivered under the TSO-led and market-led offshore electricity transmission regulatory regimes, identified from the comparative assessment of the key countries. It should be pointed out that the benefits of coordinated design become more apparent further from the shore. Closer to the shore, point-to-point connections may be the most cost effective.

- **Table 2 Coordinated offshore transmission designs and benefits for coordination**

Co-ordination	Existing Ex.[8]	Proposed Examples[8]	Rationale behind the design/potential expected benefit
1 – Sharing of long length high capacity HVDC export transmission assets via short length HVAC offshore interconnection[9].	None	Likely to be undertaken by individual developers for TCE Round 3 Zones. Any developer that has several GW within a zone is likely to be looking at how the availability of the zone can be maximised through interconnection of projects within a zone[10].	Maximum cost benefit of a HVDC connection is achieved with a single transmission circuit[11] per development which results in poor transmission availability. Interconnection significantly improves the effective availability of the offshore transmission assets to the generator. Interconnections can be alternating current (AC) and relatively low capacity without significantly reducing the benefit and are relatively inexpensive.
2 – Long length high capacity offshore HVDC interconnection.	None	None	Modestly improves the effective availability of the transmission assets to the generator. Provides some benefits of a national interconnector with the potential to bypass onshore constraints. Expensive technology needed and requires new elements such as DC circuit breakers

[8] Appendix B provides brief descriptions of the examples referenced in this table.
[9] ‘Interconnection’ here means one or several lines or cables connecting two substations.
[10] SKM has been involved in the work for East Anglia Offshore Wind, Smartwind and Forewind, all considering this coordinated design.
[11] Symmetrical monopole

Co-ordination	Existing Ex.[8]	Proposed Examples[8]	Rationale behind the design/potential expected benefit
3 – Sharing of offshore and onshore AC export transmission assets via AC offshore interconnection.	None	None	Only small improvement to the effective availability of transmission assets to the generator. Interconnections can be relatively low capacity without significantly reducing the benefits and are relatively inexpensive. Most effective for small AC developments.
4 – Sharing of onshore AC transmission assets or construction works.	A 1.5-km long hollow ducting structure across Norderney island (DE) for the connection of the first OWF Alpha Ventus.	The hollow ducting structure across Norderney island is intended to be used for several other projects (incl. BARD, Veja Mate, Global Tech I), Figure 8.	Reduced capital and lifetime O&M costs through economy of scale. Co-ordination of cable corridors minimise connection distance and avoids sterilisation.
5- International interconnection with OWF.	None	Proposed Kriegers Flak OWFs (DE/DK), Figure 9.	Benefits of an international interconnection at a reduced cost. Reduced capital and lifetime O&M costs through economies of scale with connected OWFs.
6 – Complete sharing of offshore and onshore transmission assets through offshore interconnections.	None	It is planned that Veja Mate and Global Tech 1 OWF will share one substation (BorWin 2) and export transmission cable[12], (DE), Figure 8.	Reduced capital and lifetime O&M costs through economy of scale. Modestly improves the effective availability of the transmission assets to the generator. Co-ordination of cable corridors minimise connection distance and avoids sterilisation. May require additional upfront investment.
7 – National offshore interconnection with OWFs.	None	Proposed Atlantic Wind Connection “Backbone” project (US) Moray Firth (GB), Figure 10.	Provides benefits of national interconnection bypassing onshore constraints. Reduced capital and lifetime costs through economies of scale with connected OWFs.

[12] 16 out of planned 80 wind turbines are currently in operation and exporting power to the onshore grid. Source: BARD Group http://www.bard-offshore.de/en

Co-ordination	Existing Ex.[8]	Proposed Examples[8]	Rationale behind the design/potential expected benefit
8 – Integrated Offshore Grid	None	Proposed Supergrid	International interconnection, balancing, efficiency and security Requires significant technical advancement and development of commercial and political mechanisms
9 – Deep onshore HVDC connection[13]	Connection for BARD OWF, (DE), Figure.	Onshore substation planned for BARD OWF subsequently will be expanded for Veja Mate and Global Tech1 OWFs, (DE), Figure 8.	Potentially overcomes onshore constraints Use of existing transmission assets associated with non renewable generation

[13] Due to transmission capacity constraints on the onshore transmission system it is not always possible to connect to the nearest onshore connection point and therefore one of the solutions may be to extend the offshore transmission system further inland (i.e. a deep connection).

6. Lessons Learned

From the country by country overview there is no real evidence to date that coordination has been attempted or justified. The key lessons learned are summarised below:

- Under both the TSO-led and market-led offshore electricity transmission regulatory regimes, all existing offshore transmission systems have been delivered as point-to-point connections. There is only one project currently under construction (in Germany) and just a few projects proposed employing coordinated designs (in Germany, Denmark, GB and USA), Table 2. It is however not certain that all of the proposed projects will be realised.
- Irrespective of the offshore electricity transmission regulatory regime if OWF sites are not geographically close, coordinated designs will not be feasible from an economical point of view.
- The relative timings and project development timescales between each individual project is another important factor. If the offshore projects are not developed in parallel (time-wise) and have different timescales there is less possibility for coordination under any offshore electricity transmission regulatory regime.
- Another important factor is the accessibility of required technology, e.g. high capacity cables, multi-terminal HVDC and associated equipment.

The above lessons as well as other aspects of the offshore electricity transmission regulatory regime and their impact towards delivery of coordinated offshore transmission system designs are discussed in detail in this section.

Figure 6 and Figure 7, based on the example of GB and Germany respectively, seek to provide insights into why coordination did not happen to date for either of the two offshore electricity transmission regimes.

The “see-saw” in the figures below represents the offshore electricity transmission regulatory regime for GB (market-led regime) and Germany (TSO-led regime) with colour coding for the factors that encourage coordination, discourage coordination or do not contribute. In both cases the combination of the different factor results in the tilt away from the coordinated offshore transmission system designs. Although there are differences between the underlying factors, the overall result in both Germany and GB is the same and there is no coordination to date. Notably the factors discouraging coordination are almost the same in both countries. As there is one collective connection under construction in Germany, the tilt of the “see saw” indicates that they are slightly closer to the delivery coordinated offshore transmission system designs.

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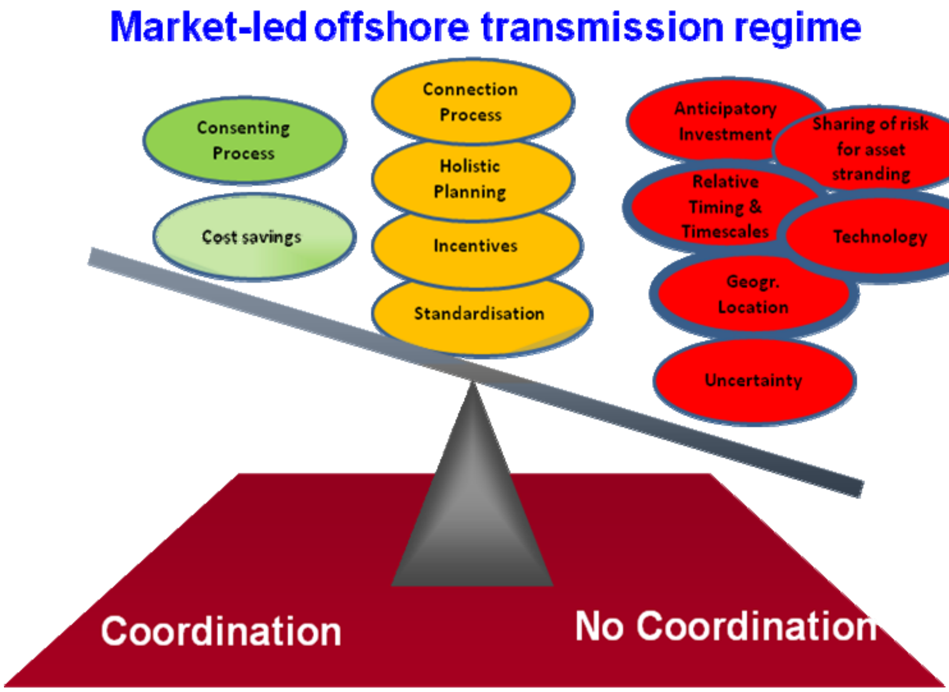
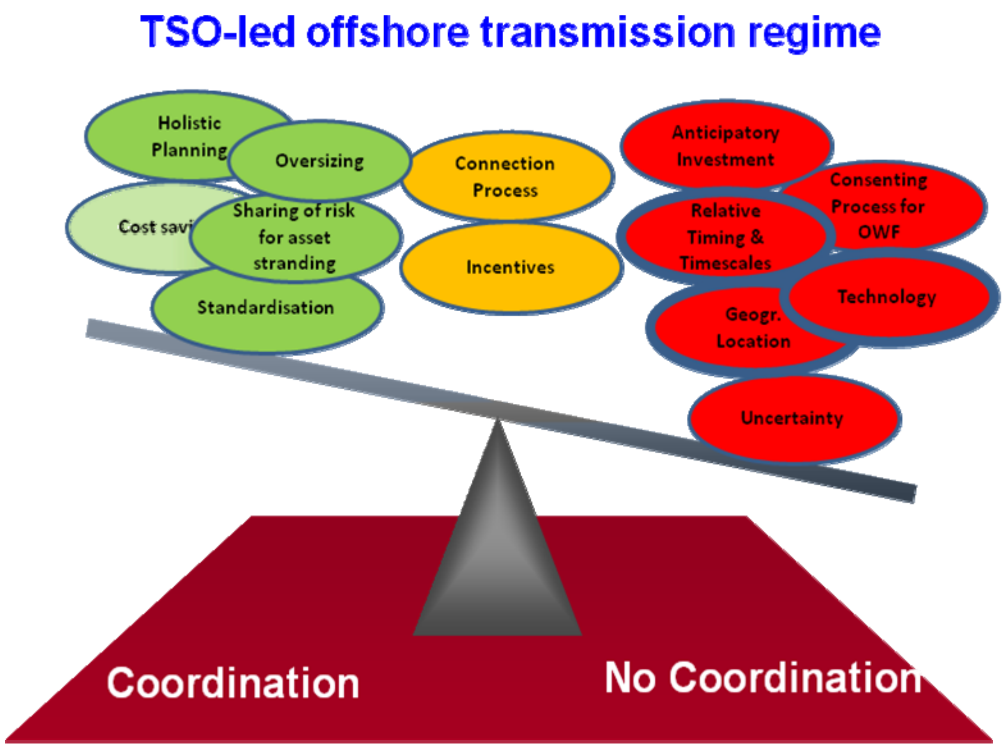


- **Figure 6 GB, Offshore Transmission Coordination**



- **Figure 7 Germany, Offshore Transmission Coordination**

The case for coordination is primarily driven by the location of the OWFs. Currently, when sites are identified for development, little consideration is given to coordination of the offshore transmission assets. Other factors driving site selection include sea depth, distance from shore, fishing areas etc. This is why a point-to-point connection often is the cheapest option.

The relative timings and project development timescales between each individual project is another major factor. Starting from the sea bed lease and throughout offshore project development stages, the importance of relative timing and development timescales between individual projects for delivery of coordinated designs is rarely considered. For example in Denmark, sites are decided by the Government and awarded via a competitive tender process. However there is no set time window for the tender process and, thus, no certainty as to when the next tender will be held and for which site. Hence the design of the tendering process does not make provision for the delivery of coordinated transmission system designs, except for the case of international interconnections (e.g. Kriegers Flak). In GB each of the nine Round 3 zones were awarded to single consortia of developers, which is likely to lead to phased developments on a project-by-project basis within each zone. Collective connections will therefore be unlikely as these would call for anticipatory investment in offshore transmission assets. It is possible that some individual projects within a zone may be interconnected at a later stage for improved effective availability of the offshore transmission system.

Another important factor is the accessibility of the required technology. At present, the largest offshore HVDC line in operation is 400MW, through there is currently an 800MW HVDC line under construction. Additionally, it should be noted that designs exist for 1,000MW and 1,200MW. Up to 2,000MW is expected in the near future but issues will arise due to the current size of offshore platforms. Multi-terminal HVDC technology and associated assets (DC circuit breakers, fault blocking) are still under development.

From the perspective of an offshore electricity transmission regulatory regime, the table below discusses the potential reasons to why only point-to-point connections have been delivered to date and coordination has not occurred in any of the studied countries. The table discusses the current situation and also possibilities under both of the broad offshore electricity transmission regulatory regimes.

- **Table 3 Observations on why coordination did not happen under the TSO-led and market-led approaches and the potential for coordination?**

Co-ordinated designs	TSO-led approach	Market-led approach
1 – Sharing of long length high capacity HVDC export transmission assets via short length offshore	Projects need to be close to each other and develop at the same time/within similar timescales to be considered for interconnection under both regimes or otherwise anticipatory investment will be required.	
	In Germany consenting process takes a long time and thus the projects are still	Whilst not supported by evidence of coordination it would seem that

<table>
<tr><th>Co-ordinated designs</th><th>TSO-led approach</th><th>Market-led approach</th></tr>
<tr><td>interconnection.
3 – Sharing of offshore and onshore AC export transmission assets via offshore interconnection.

Note: the aim of these coordinated designs is to increase availability of the transmission infrastructure for wind power export.</td><td>developing individually even though the procedure for coordinated connections is in place.

In Denmark sites are chosen by the Government individually and there is set window for tender[14], so the development of the sites is happening individually.

It is not clear whether the TSO is incentivised to find a trade-off between minimum cost of connection and increased transmission availability for the generators?</td><td>projects developed by one developer or offshore transmission systems developed by one TAO are more likely to choose these designs within their own development zone to maximise its availability through interconnection of the projects (e.g. plans for Round 3 developments).

Availability considerations may lead to utilisation of coordinated designs. For Round 3, the only way to achieve T1[15] availability levels will be to have interconnection (see example in the textbox below). Round 3 availability incentive has not yet been set and T2 availability incentive is under review.</td></tr>
<tr><td rowspan="2">2 – Long length high capacity offshore HVDC interconnection.
7 – National offshore interconnection with OWFs.
5- International interconnection with OWF.
8 – Integrated Offshore Grid</td><td colspan="2">These options are expensive; involve new unproven technologies (e.g. multi-terminal HVDC hubs and DC circuit breakers).

There are no common support schemes for renewables in neighbouring countries. International interconnection raises a problem of renewable trading. This requires commercial and political mechanisms[16].</td></tr>
<tr><td>International interconnections and Integrated Offshore Grid designs require active involvement of the TSOs and thus TSO-led approach is more suitable for this kind of coordinated design (e.g. Kriegers Flak proposed in Germany/Denmark).

These types of coordinated design may happen in the future provided there are benefits for the onshore system(s) and economy of scale.</td><td>There are no actual barriers for these designs to take place under market-led approach but it requires substantial cooperation between OWFs, offshore TAOs and active involvement of onshore TAO/TSO (e.g. design 7 is considered for connection of Moray Firth OWF in Scotland, in conjunction with onshore grid development with considerable involvement of onshore TAO).

There is no clarity on how the costs of the shared infrastructure will be split by generator developers and onshore TAOs (provided that national or international interconnectors benefit all stakeholders.</td></tr>
<tr><td>4 – Sharing of onshore AC transmission assets</td><td colspan="2">Projects need to be close to each other and develop at the same time/within similar timescales to be considered for sharing, or otherwise anticipatory</td></tr>
</table>

[14] Horns Rev 2 site was tendered for 2007, Rodsand 1 and 2 in 2008 and Anholt in 2010.

[15] T1 and T2 – the first and the second transitional OFTO tender rounds

[16] SKM was appointed by DECC to carry out the study on “Offshore Grid Development for a Secure Renewable Future – a UK Perspective”. One of the main conclusions of the study was that creating an international interconnector via an OWF is less cost efficient than bespoke international interconnectors.

Co-ordinated designs	TSO-led approach	Market-led approach
or construction works.	investment will be required.	
6 – Complete sharing of offshore and onshore assets through offshore interconnection.	In Germany, a 1.5-km long hollow ducting structure was completed across Norderney island for connection of the first OWF Alpha Ventus. This structure will be used by cables for several other projects (incl. BARD, Veja Mate, Global Tech I), Figure 8.	In GB this can theoretically happen for the projects within same Round 3 zone. However either the timelines for the projects need to be coordinated or substantial anticipatory investment should take place.
	In Germany Veja Mate OWF and Global Tech 1 will be the first to share the offshore transmission line and offshore substation, Figure 8.	
9 – Deep onshore HVDC connection	Applicable only in specific cases, requires clarity in how connection costs are attributed.	
	Planned in Germany for connection of BARD OWF and subsequently will be used by Veja Mate and Global Tech 1 OWF.	Depends on individual connection offers or developer approaches.

Example illustrating potential advantages from interconnection of individual OWFs in terms of effective availability of the transmission asset:

In view of the relative distances of the Round 3 sites, HVDC connections will be the only option for many OWF projects. Therefore as a result of the high HVDC connection costs involved, it is expected that an OWF will be connected to an onshore transmission system with a high capacity single circuit line. However a single circuit line has a very poor availability (about 95%) whereas the outage of the line would result in a complete loss of the export capacity. This situation then means that the OWF will not meet the 98% availability target.

Consider a case of two OWFs which are relatively close to one another and has a dedicated HVDC point-to point connections to the onshore transmission system with each dimensioned for 100 % of the respective OWF installed capacity. It is well established that due to the variability of wind, the OWFs do not always generate at full power and therefore have a low capacity factor. If the OWFs are AC interconnected, without any additional capacity, then because the OWFs will generally mirror each other in terms of output it will be possible to export the vast majority of the actual generated energy in the event of an outage of one of the HVDC circuits. Even though the capacity availability[17] is the same value with or without the AC interconnection, the energy weighted

[17] *Capacity availability – availability of export transmission capacity corresponding to 100% of installed capacity of an OWF*

availability[18] becomes approximately 98.6%. This represents a significant increase reflecting the fact that the number of connection circuits has effectively been doubled, i.e. the availability is similar to having a single development with two HVDC lines. This increase in availability is likely to prove financially attractive for OWFs which are in close proximity to one another.

Overall, there is very limited direct evidence as to whether either of two broad offshore electricity transmission regulatory regimes is more likely to encourage coordination. Additionally the offshore electricity transmission regulatory regimes in some of the countries are still under development or undergoing constant changes, the consequences of which are not yet visible in the development of offshore transmission systems. Any further assessment therefore needs to consider theoretical pros and cons of the two approaches and their likely impact on coordination. Lessons can be learned from the key characteristics of each approach rather than the results based on the experiences.

Overall offshore transmission system planning and standardisation of assets

Centralized planning in the TSO-led approach is intuitively more likely to deliver coordinated offshore transmission system designs. This is because the overall transmission system construction is done by the same organization that holds all information about the entire power system, onshore and offshore as well as information regarding future onshore and offshore development. The TSO is already providing this for development of the onshore transmission system to meet increases in demand and is more likely to have proven procedures in place for such planning.

Without centralized planning it may be more difficult to find the most socio-economic offshore transmission system solutions because the decisions will tend to be made on the basis of the least cost for an individual project, rather than from the perspective of the entire system. This is especially true for coordinated designs 7, 5 and 6, see Table 2 and Table 3. These are likely to offer other benefits for the onshore transmission system, e.g. relieving onshore transmission constraints or providing international interconnection. Such benefits may only be identified from the holistic transmission system planning exercise. However, holistic planning can also exist under market-led approaches where there is still some central body having oversight and a role in the process.

Equally, it should be pointed out that in certain cases, where OWF location is close to shore, point-to-point connection may well be the optimal solution, delivering lowest cost connections without missing any other potential benefits. If this is the case there are no barriers within either of the offshore electricity transmission regulatory regimes to prevent such a solution from being identified as the most optimal.

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[18] E*nergy weighted availability (effective availability) – availability of necessary export transmission capacity to transfer actual energy production of an OWF*

Provisions for centralized overall transmission system planning can also be made under a market-led approach, where the overall transmission system planning combined with batch processing of connection applications, as e.g. in Ireland, or the integrateable offers being made to offshore developers in GB. This may lead to the proposal of coordinated solutions in the connection offer, where deemed more efficient. The delivery of these coordinated solutions in the most cost effective and time efficient manner will be the responsibility of the stakeholders involved. The identification of the appropriate incentives is likely to be an important element to facilitate such coordination.

<u>Construction of offshore transmission system</u>

There are provisions to lift the upfront financial burden from the OWF developer under both the TSO-led and market-led approaches (e.g. GB under OFTO build option). Both build approaches can introduce a risk of OWF stranding due to potential delays in the delivery of the offshore transmission assets. The GB offshore electricity regulatory regime provides the OWF developer with an opportunity to weigh benefits versus the risk of different build options and choose the preferred option (generator build or OFTO build).

In both countries currently employing a TSO-led approach (Germany and Denmark), there are set timelines not only for processing of connection applications but also for construction of offshore transmission systems, which provides certainty to OWF developers. However, one potential downside of the TSO approach is the reliance on a single party delivering all connections, whereas in the market-led approach the financial risk is spread across multiple generator and OFTOs investors. [19]In terms of the construction of the coordinated offshore transmission systems, a TSO-led approach has the advantage of one body bearing the responsibility for the delivery of all offshore transmission system, which may make the development of some offshore transmission projects more manageable as it could reduce complexity.

For a market-led approach, this will only apply to the cases where one developer is responsible for the delivery of the entire coordinated offshore transmission infrastructure. For example, in GB this may be the case where one OFTO is appointed to build a coordinated offshore transmission system to several projects. However, there is currently no driver or mechanism for a potential OFTO to choose this path.

<u>Shared offshore transmission assets</u>

There is no sharing of the offshore transmission assets to date. Theoretically, there are no barriers preventing the sharing of offshore or onshore transmission assets under either of the two offshore

[19] The German TSO, TenneT, has recently written to the German Government to inform it of its problems in constructing connections for OWFs in the North Sea, citing a lack of human, material and financial resources.

electricity transmission regulatory regimes. In the TSO-led approach, centralised transmission planning is a driver for coordinated solutions with shared use of transmission assets, where deemed more efficient, similarly to onshore transmission system planning and expansion. The TSO as one planning, designing, connecting and constructing entity is bound by its license to seek cost efficient coordinated connection solutions, where appropriate. The evidence of this can be seen in the TenneT and 50Hertz transmission system development plans, which extend offshore and envisages the connection of future OWFs via shared collective connections.

In the market-led approach, a similar driver for delivery of the coordinated solutions with shared transmission assets is generally not present[20].

As seen in Table 2, there are coordinated designs that provide higher availability of transmission assets to the interconnected OWFs, at a marginal incremental cost. The objective of the TSO, however, is to minimise cost of connections and it is not clear if consideration is being given to the value of energy lost from the OWFs in case of connection outage.

On the other hand, as shown in the textbox example above, the availability incentives introduced in GB could lead to implementation of these coordinated designs (design 1 and 3).

<u>Anticipatory investment, oversizing</u>

Both TSO-led and market-led approaches make provisions for anticipatory onshore transmission system reinforcements (e.g. Germany as a result of the DENA study and GB as a result of the ENSG study and TII).

There is no offshore anticipatory investment[21] or oversizing to date. The two examples of planned anticipatory investments in the future are the Atlantic Backbone and Moray Firth HVDC Hub. However these are very specific examples, as the main purpose of the backbone is to lift congestions from the onshore transmission system and main purpose of the proposed Moray Firth HVDC Hub is to connect Shetland with mainland Scotland.

Oversizing of offshore platform, where deemed more efficient for the connection of future projects and solutions allowing modular extension of offshore substation, is promoted in Germany[22]. There is also a provision for oversized collective connections or even collective connections with maximum technically possible transmission capacity where deemed efficient. The construction of

[20] Except for Ireland, where group processing approach for connection of OWFs exists, see Deliverable 1 report. However there are other barriers for OWF development in Ireland and currently no projects that are close enough and in the same development stage for coordinated connections to happen.
[21] Lessons can be learned from Deliverable 3, Sector: Onshore electricity transmission system, Texas.
[22] Lessons can be learned from Deliverable 3, Sector: Gas entry points

such oversized transmission systems has to be backed up by at least one OWF, having fulfilled 4 connection criteria and the others in the vicinity holding necessary planning permits and consents, but not yet applying for connection.

In GB the OFTOs have incentives to expand capacity, through capital expenditure (up to a limit of circa 20% of transfer value, subject to approval by the Authority) and through innovative options which increase capacity without capital expenditure.

User commitment/financial security, transmission charging

Under the TSO-led approach the offshore transmission system is funded by the TSO and guarantees are required from the OWF developers, which may either be financial or a set project progress criteria (e.g. Germany).

Under the market-led approach, the offshore transmission system is either funded by the generator developer or by the offshore TAO. The latter case brings about the same advantages as a TSO-led approach by lifting the burden of upfront transmission asset costs from the generator developers. Under a market-led approach, financial guarantees are required from the generators.

Under the TSO-led approach (excl. France), the costs of the offshore transmission assets are levied on all demand customers through TNUoS tariffs.

Under the market-led approach, the costs of the offshore transmission assets and associated wider onshore transmission reinforcements are recovered through the TNUoS tariffs and split between generators and demand customers (e.g. GB, Ireland, Sweden). It should be pointed out that in GB, under the current transmission charging regime, projects with interconnections would face higher TNUoS charges or higher Capex charges compared to point-to-point connections. However it is worth noting that the transmission charging methodology is currently under review.

Consenting for offshore and onshore transmission infrastructure

The TSO is obliged by law to connect the OWFs. Under the TSO-led approach consenting of the offshore transmission system for an OWF is the responsibility of the TSO. This means that:

- Uncertainty is removed for the OWF developer, because if consent for a bespoke offshore transmission system is not obtained another route will be sought by the TSO to make the connection possible.
- If a coordinated offshore transmission system design is chosen there is one body responsible for obtaining consent for all shared transmission assets.

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Timelines for offshore connection

From the existing projects it is not conclusive as to which of the two broad offshore electricity transmission regulatory regime approaches delivers faster connections. Though the timelines are inherently dependent on the offshore electricity transmission regulatory regimes, there were other factors contributing such as distance to shore, water depth etc.

It should be pointed out however that in the countries with TSO-led approach (Denmark and Germany), there are currently set timelines for establishing the connection (coordinated or not), whereas in other countries with a market-led approach (as e.g. GB and Ireland), the timelines are fixed only for processing of the connection applications.

6.1. Broad characteristics of the offshore transmission regime encouraging delivery of coordinated offshore transmission designs

Based on the lessons learned from the comparative assessment of the offshore electricity transmission regulatory regimes in the key countries and the above discussion on coordinated offshore transmission system designs, characteristics of offshore electricity transmission regulatory regimes promoting delivery of coordinated transmission designs can be considered.

6.1.1. How development zones are identified and leased

Projects need to be coordinated geographically, with consideration given to project size. Long-term strategic planning for the future use of offshore zones may improve the prospects for OWF deployment through the avoidance of potential stakeholder conflicts and improvement in grid connection efficiency when considering zone geography and size.

Techno-economic and environmental feasibility for OWFs and associated offshore transmission assets can be assessed at a national strategic level prior to the award of any sites for development.

6.1.2. Who constructs, owns, operates and maintains the offshore transmission system

It would be beneficial to have an arrangement which allows a single body to be appointed for any shared offshore and onshore transmission assets to assist project delivery and reduce uncertainty.

6.1.3. Offshore transmission planning and standardisation

Holistic planning, as a part of onshore transmission system development plans, is likely to encourage coordination with the TSO taking an active part in development of coordinated offshore transmission system designs. This is because the TSO has exclusive knowledge and experience with the national onshore transmission system. It may be useful to produce a guideline business case for coordination rather than leaving the decision to individual project developers. For example the cost of point-to-point connections for the OWFs concerned and the cost of interconnector (without the OWF) could be benchmarked against the coordinated solutions when considering designs 7 and 8.

The holistic plan may seek to find the cheapest GBP/MW for OWF connections seen from the onshore connection point but also consider benefits of coordinated designs, such as designs 7, 8, 9 in Table 2, for the entire national transmission system.

For an integrated offshore transmission system, a higher degree of standardisation for the transmission assets is required, see Deliverable 1 report for detailed rationale. This would particularly apply to HVDC transmission systems where the operating voltages need to be standardised and in the case where various suppliers have HVDC equipment connected to a HVDC grid, then the communication between control systems need to be compatible. Potential advantages of a standardised design is the ability to achieve lower capital and operating costs for the offshore transmission system, and lower risk, as designs are already proven.

Additionally, standardised designs may facilitate coordination, allowing modular expansion of the offshore transmission system and decreasing the need for anticipatory investment. With standardised designs it will become possible to interconnect projects at later stages and as multi-terminal HVDC technology develops, thus making future offshore grids possible.

A potential disadvantage with standardisation is that it becomes more difficult to manage innovation in the design. The balance between the benefits of standardisation and need for innovation is addressed in the work of CIGRE WG B3.11[23], though specific quantification of benefits is not provided.

6.1.4. Connection process and timelines

Connection applications can be processed in batches, during specific time windows, to facilitate coordinated connections of OWFs. Project progress criteria may be used as part of the connection application process to ensure that projects applying for connection are at a similar development stage. Delivery of the coordinated offshore transmission system solutions, if deemed more cost efficient, can be administered via joint connection offers (as e.g. in Ireland). The window for connection applications should be relatively frequent (as e.g. in Germany), as otherwise the developers that did not meet the application deadline will face the prospect of severe delays with their connections (as e.g. in Ireland).

[23] CIGRE Brochure No 389 "Combining Innovation with Standardisation"

Realistic but fixed deadlines may be introduced to prompt the timely delivery of offshore transmission assets for deployment of OWFs in question (as e.g. in Germany)[24].

6.1.5. Shared assets

Where sharing the offshore transmission system is deemed to be cost efficient, this could be taken into account in the connection offer to the respective OWFs and followed by tenders to deliver conceptual coordinated design identified in the connection offer. The tender may be awarded to the developer proposing the most cost effective realisation of the predefined coordinated design.

If the TSO does not take an active role during the connection process incentivising shared offshore transmission systems, where deemed efficient, there is a risk that even in the future the connections will continue to be delivered as point-to-point.

6.1.6. Anticipatory investment/oversizing

Anticipatory reinforcements onshore can take place as a result of the holistic planning as in Germany and GB. Additionally the Connect and Manage approach (similar to GB) may be applied; this would allow projects to connect based on the time taken to complete its ‘enabling works’ (i.e. ahead of the completion of wider national transmission system reinforcements, which will be completed at a later date).

For offshore connections, modular solutions allowing future extensions should be promoted. Where it is deemed efficient and in order to achieve economy of scales, specific oversizing (offshore platform, Environmental Impact Assessment (EIA) and consent for wider transmission corridors in anticipation of future projects) may be encouraged.

6.1.7. Financial

Costs of the offshore transmission infrastructure constitute 10-30% of total OWF project costs. There is thus a clear benefit in lifting a burden of upfront funding of offshore transmission assets from generator developers. This can be achieved if the offshore TAO or national TSO funds the offshore transmission assets (though it may of course be financially constrained, as noted in section 6) . Well defined project development criteria need to be provided by generators as a guarantee and in some cases financial guarantees may also be required.

Where a coordinated solution is deemed to be more cost effective but requires anticipatory investment/oversizing, the costs of these assets should not be borne by the first OWFs to connect

[24] Note that according to [4] this is one of the factors why Germany is considered as favourable environment for the investment in OWFs.

but shared between all network users (generators and load), as part of these costs can be recovered from the later OWFs using the infrastructure (similar to Ireland)).

6.1.8. Consenting of offshore transmission infrastructure

The consenting process should utilise a "one-stop-shop" approach. It should be possible to simultaneously seek consent for OWFs and the associated offshore transmission system (similar to GB).

Where a coordinated offshore transmission design is recommended procedures should be put in place so that the consenting process for additional capacity becomes easier.

7. Conclusions

From analysis of the country by country overview there is no real evidence that coordination has been attempted or justified for offshore transmission. Under both TSO-led and market-led offshore transmission regimes all existing OWF connections to date have been delivered with point-to-point connections. There is therefore limited direct evidence as to whether other regimes are more likely to encourage coordination than the offshore transmission regime in GB.

It should be recognised that the offshore transmission system is not the key investment driver for OWF, whilst it is one of the factors underpinning the investment decision; it is certainly not the key factor. At a fundamental level the investment question will be: "Can the OWF make money?" Currently the UK offers a very attractive investment climate which has substantially helped spur the investment. Also there have been many site leases agreed with TCE, so the potential 'pool' of OWFs is much larger in the UK.

The investment decisions will be driven more by the location of the OWFs and other factors such as sea depth rather than offshore transmission considerations. When sites are identified for development, little consideration is given to potential coordination of transmission assets.

Without some form of geographic coordination, when identifying site for future OWF development, there will be no possibility for coordinated offshore transmission systems to be delivered. Long-term strategic planning for the future use of offshore zones may improve the prospects for offshore wind deployment through the avoidance of potential stakeholder conflicts and improvement in grid connection efficiency considering zone geography and size.

Irrespective of the offshore transmission regulatory regime, the key drivers to determine the level of coordination that is possible to achieve for both the offshore transmission system and at the onshore connection point will remain the geographical location of OWFs and relative timing and timescales of individual projects.

A key question addressed is whether any offshore regime has hampered development in anyway, or whether one approach is better than the other as it removes barriers. On the basis of this comparative study it is not possible to conclude whether one overall approach favours coordination, however characteristics that are more likely to encourage coordination can be identified.

The TSO-led approach, as a single-body managed approach, should theoretically enable more co-ordinated solutions, but there is inconclusive evidence to support this so far, given that point-to-point has been the most efficient solution to date regardless of the TSO or market-led approach.

8. References

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Appendix A

The following Table 4 discusses stages of the offshore project development and cooperation between the stakeholders involved which could help to achieve each of the coordinated designs introduced in Figure 5. Implications for each generic coordination option are also discussed. In Table 4 the designs calling for cooperation at the same stages of offshore project development are grouped.

- **Table 4 Requirement for coordination and cooperation, User commitment/financial security, anticipatory build.**

Co-ordinated designs	Where coordination and cooperation would be required?	What are the implications of coordination and cooperation?
1 – Sharing of long length high capacity HVDC export transmission assets via short length offshore interconnection. 3 – Sharing of offshore and onshore AC export transmission assets via offshore interconnection.	- Early design of the projects to take interconnection into account - Combined EIA, including consent for interconnector(s) - Standardisation (e.g. voltage levels in HVDC case) - During construction of interconnector(s) - Ownership and O&M	- Interconnection has to be taken into account for offshore substation design and construction. Hence marginal anticipatory investment by each interconnected project - Costs of the interconnector(s) are shared between projects but depending on respective timings anticipatory investment could be significant
2 – Long length high capacity offshore HVDC interconnection.	- Early design of the projects to take interconnection into account - Design of the projects in coordination with overall onshore transmission system planning. - Combined EIA, including consent for interconnector - Standardisation essential - Construction of interconnector(s) - Ownership and O&M	- Interconnection should be taken into account for offshore substation design and construction. Involves Expensive technology and new elements required, such as DC circuit breakers, hence significant anticipatory investment needed. - Guarantees/financial security will be required from the generator developers - Costs of the interconnector(s) shared between projects
4 – Sharing of onshore AC transmission assets or construction works. 6 – Complete sharing of offshore and onshore transmission assets through offshore interconnection.	- Early design of the projects - Combined EIA, including consent for shared transmission assets - Connection process - Construction of shared transmission assets - Ownership and O&M	- Effectively becomes a joint project - Guarantees/financial security will be required from the generator developers/TAOs - Financial guarantees paid to national transmission system operator (if any) will be shared between two projects - Costs of the shared onshore transmission assets will be shared between projects - May require additional upfront investment

Co-ordinated designs	Where coordination and cooperation would be required?	What are the implications of coordination and cooperation?
5- International interconnection with wind generation. 8 – Integrated Offshore Grid	- Design of the project fundamentally has to take interconnection into account - Design of the projects in coordination with overall onshore transmission system planning in the interconnected countries. - Combined EIA, including consent for interconnector - Standardisation essential - Construction of interconnector(s) - Ownership and O&M - Trading of renewable between interconnected countries	- Effectively becomes a joint project - Likely to require substantial guarantees/financial security from the generators - Likely to involve anticipatory build - Financial guarantees paid to the national transmission system operator (if any) will be shared between the generators involved - Costs of the shared transmission assets will be shared by generator developers and onshore transmission system owners (provided that interconnectors benefits all stakeholders)
7 – National offshore interconnection with wind generation.	- Design of the projects in coordination with overall onshore transmission system planning. - EIA, including consent for the national offshore interconnector - Benefits from standardisation will have benefits - Construction of the OWF and interconnector - Ownership and O&M	- Likely to involve anticipatory build - Financial guarantees paid to the national transmission system operator (if any) will be shared between generators involved - Costs of the shared infrastructure will be shared by generator developers and onshore transmission owners (provided that interconnectors benefits all stakeholders) - May result in an agreement on potential socialising of costs?
9 – Deep onshore HVDC connection	- Design of the project in coordination with the onshore transmission system planning. - Ownership and O&M on shared onshore transmission assets	- Not different from point-to-point OWF connection if the onshore connection point is confirmed by TSO. - Agreement on how cost savings might be balanced against increased costs of connection. - Potential difference in connection charge.

Appendix B

There are several projects under development that may allow some of the benefits of coordination to be realised in the future.

B.1 BorWin 1 and BorWin 2

The first project that involves direct current technology was the grid connection for the BARD Offshore 1 wind farm. An offshore HVDC converter station BorWin1 was provided by TenneT for transporting the wind energy to land through 200km long HVDC transmission line with a capacity of 400MW, Figure 8.

Several kilometres of cable were already laid in 2008 for the grid connection on shore. The rest of the total of 200km followed in 2009 through the island of Norderney down to the substation Diele where the direct current is then again transformed into three-phase AC and fed into the 380 kilovolt grid. This is the longest connection in the world to be built for a grid connection for an OWF. The land route from Hilgenriedersiel to Diele is around 75km long. Around 125km of cable was also laid through the tidal flats and offshore [1]. Currently 16 wind turbines of BARD OWF are already connected to the grid [2].

The first 800MW and 200km long direct current connection is being realised by TenneT in the context of the BorWin2 project, Figure 8. The wind parks Global Tech 1 and Veja Mate located 125km off the coast can use this connection in the future to feed large quantities of wind energy into the power grid.

The land line from Hilgenriedersiel to Diele is approx. 75km long and runs parallel to the first line for the BorWin1 project. In July 2010, TenneT started with the preparatory horizontal drilling on Norderney and in Hilgenriedersiel for the passage of the direct current cable system. The laying of the land cable and will follow in 2011. The laying of the 125km sea cable and the erection of the converter platform at sea are planned for 2012. Parallel to this work, the grid junction in the voltage transformation substation in Diele will be further expanded.

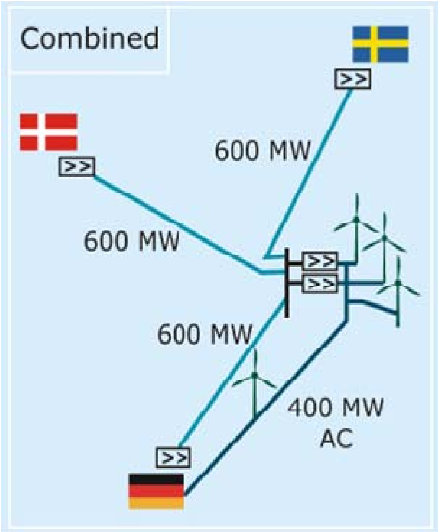
Figure 8 BorWin1 and BorWin2 projects

B.2 Kriegers Flak

Kriegers Flak, a triple project (potentially 3x600MW) on the Exclusive Economic Zone (EEZ) borders of Sweden, Germany and Denmark. According to the feasibility study conducted by the three TSOs involved (50Hertz, Energinet.dk and Svenska Kraftnät), it is envisaged that the projects will be AC with HVDC connections to each country and with AC interconnections between the three OWF. This could become a forerunner of the European Super grid [3]. Although Svenska Kraftnät (SvK), the Swedish grid operator has pulled out, the German and Danish projects are still planning to go ahead.

Planning for the German Kriegers Flak wind farm (EnBW Baltic 1) has already started. According to the latest information however, the size of the OWF is expected to be 288MW [4]. The transmission capacity will be adjusted accordingly (one AC cable will be laid between EnBW Baltic 2 and Baltic 1 OWF in a first step).

It is expected that the next tender in Denmark will be for a 600MW OWF at Kriegers Flak.



- **Figure 9 Kriegers Flak OWFs, interconnection envisaged in the feasibility study conducted by three TSOs involved [3].**

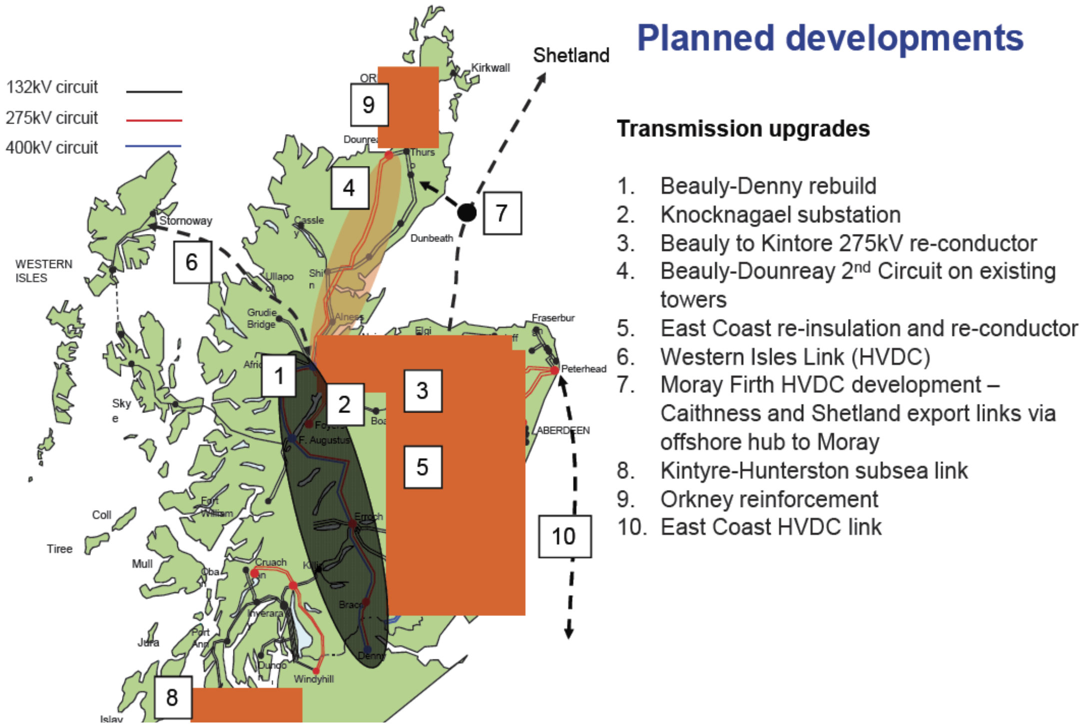
B.3 Moray Firth Hub

The Moray Firth Offshore HVDC Hub is innovative and challenging proposal. It is envisaged that the project would develop an offshore HVDC connector hub, with the provision of a three way inverter station, to enable offshore renewable energy projects in the Pentland Firth area and adjacent OWF projects (e.g. Moray Firth OWF) to connect to the proposed sub-sea cable running from Shetland to the Scottish mainland.

The project is led by Scottish Hydro Electric Transmission Limited (SHETL), part of Scottish and Southern Energy (SSE) is the owner of onshore transmission network. The project is planned as reinforcement of the onshore transmission network in the far north of Scotland to accommodate future onshore and offshore renewable generation in the area and in Orkney and Shetland. Project comprises, Figure 10:

- An HVDC link from Caithness to Moray with an offshore "hub" and onshore reinforcement in Caithness.
- Shetland link. A new 600MW HVDC link between Upper Kergord on Shetland to the proposed offshore HVDC hub in the Moray Firth, then onto Blackhillock in Moray. This link will consist of 320km of subsea and 25km of onshore underground cable with HVDC converter stations at each end. It will allow for new large and small generation schemes on Shetland.

Note the above are two different links, i.e. Caithness to Moray via Moray Firth Hub and Shetland to Moray through the Moray hub. Various information sources state that the hub is planned as three terminal, so it is not clear where Moray OWF would connect.



- **Figure 10 Planned developments of SHETL transmission system including Moray Firth Hub (7).**

In December 2009, SHETL (Scottish Hydro-Electric Transmission Limited) was successful in gaining 50% grant from the European Commission funding up to EUR 74.1M for the project, under the European Energy Programme for Recovery (EEPR). The hub and incremental works project is a strategic investment that is unlikely to be economic without the grant funding.

SHETL consider the offshore hub to represent an economic and efficient development of the transmission system in the North of Scotland. SHETL's preliminary analysis suggests this would be the most economic means to accommodate new generation connections in the far north; e.g. the initial proposed marine generation in and around Orkney and the Pentland Firth or offshore wind in the Moray Firth. In addition the project would bring an innovation benefit of proving multi terminal HVDC technology essential for the realisation of large scale offshore generation. The project uses an integrated approach for offshore connections leading towards a future offshore super grid. Indicative timescales are given as:

- 2010 – Consultation with stakeholders commences

- 2012 – Application for consent
- 2014 – Construction Commences
- 2016 – Anticipated First Generation, although these may change as the project develops.

B.4 References

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