North Sea
Wind Power Hub
Programme

Regulatory & market design

Governance Models for Hub-and-Spoke Projects

Discussion paper

#1

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Preface

The present paper on the Governance Models for Hub-and Spoke Projects has been discussed in the first half of 2021 and finalised in September 2021. The paper has not been published at the time for practical reasons, but shared and discussed with various public authorities. North Sea Wind Power Hub yet publishes this paper in the version finalised last year in order present to the public the results of its work.

In this paper, major developments that have taken place since September 2021 and that have a significant impact on the Hub-and-Spoke Projects developed by North Sea Wind Power Hub are not reflected.

One of these major developments is the publication by the European Commission of the EU framework to decarbonise gas markets, promote hydrogen and reduce methane emissions on 15 December 2021. The publication of this draft and the subsequent legislative process provide an outlook into the future roles and responsibilities of the various participants on the hydrogen market, both onshore and offshore. On a national level, since the early summer of 2021 the Dutch government has taken firm steps to create a national hydrogen market, amongst other by providing detailed rules for setting up a (onshore) hydrogen transport network in phases until 2030 and by tasking Hynetwork Services, a 100% subsidiary of N.V. Nederlandse Gasunie, to build and operate this network[a]. In Germany, various TSOs and private parties aim to set up the necessary hydrogen infrastructure and the projects along the value chain, in line with the National Hydrogen Strategy of the Federal Government[b]. In Denmark, the government has in 2022 published a strategy for hydrogen and PtX that pushes for the rollout of support for PtX products, national hydrogen market regulation, and establishes a Hydrogen Network[c] mandate for the operation of hydrogen infrastructure[d].

Another major development is the increase in targets for production of renewable energies, onshore and offshore by the REPowerEU plan published by the European Commission on 18 May 2022[e]. With respect to the North Sea, Denmark, Belgium, the Netherlands and Germany have signed the Esbjerg Declaration on the North Sea as a Green Power Plant of Europe, setting the target of 65 GW offshore wind in 2030 and 150 GW in 2050 and the target of 20 GW onshore and offshore green hydrogen production capacity in 2030[f]. The increase in renewable energies targets highlights the importance of strong system integration.

A last major development to mention is the greater importance North Sea Wind Power Hub has given to the role of offshore hydrogen and system integration in its work. North Sea Wind Power Hub reflects on the impact of these major development in its work. It intends to publish further papers that take the impact of those major developments on the Hub-and-Spoke Projects into account, including a further paper on the Governance Models for Hub-and Spoke Projects.

[a] Link
[b] Link
[c] Article 2 (22) of the Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal markets in renewable and natural gases and in hydrogen 2021/803, Link
[d] Link
[e] Link
[f] Link

About this paper

Why read this report

To develop hub-and-spoke projects that connect and integrate large scale offshore wind, it is necessary to evaluate the roles and responsibilities of project stakeholders over project phases and assets. A governance model prescribes exactly that, however, given the complexity of the hub-and-spoke concept, a suitable and feasible comprehensive governance model is yet to be defined. Existing governance models can be used in developing a suitable tailor-made model for the hub-and-spoke concept. This paper addresses existing, conventional governance models for offshore wind, interconnection, natural gas, and energy storage; for Denmark, Germany, the Netherlands, and the UK. Moreover, an overview of the latest trends and developments in governance models for offshore wind, hydrogen assets and infrastructure, and cross border infrastructure. Using these insights, a description of a suitable and feasible governance model for a first hub-and-spoke project is presented in combination with decisions that need to be taken. Finally, recommendations of next steps are provided.

Highlights

The novel approach of hub-and-spoke projects calls for a re-assessment of roles and responsibilities in planning, ownership, and operation of assets.

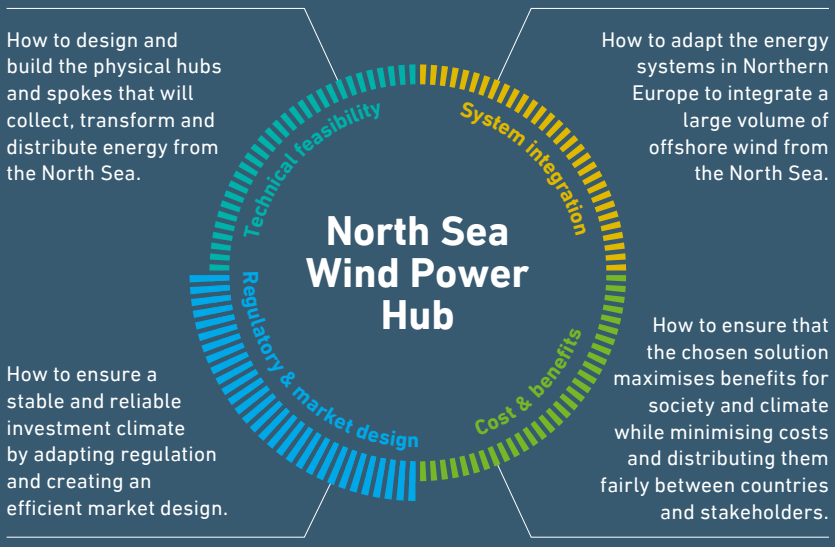
The centralised approach seems best suited and can result in benefits like system planning and design optimization, economic efficiency, a fit with current and future policies, and speed of implementation.

A potential hub-and-spoke governance model system planning can be done by a consortium of national TSOs, ownership and operation of infrastructure assets may be assigned to national entities or TSOs. While this is similar to the status-quo, decisions need to be taken by governements on new aspects such as the hub foundation, system planning responsibility and interconnectors between national hubs.

The big picture

The North Sea is a powerhouse of wind energy. Harnessing this power requires us to cooperate across countries and borders to build an efficient network. To show that a solution can be achieved in a cost-effective and secure manner, the North Sea Wind Power Hub is working within four key areas.

This discussion paper explores key topics within regulatory & market design.



Executive summary

The hub-and-spoke concept offers a solution to the challenge of integrating offshore renewable energy to onshore energy systems in a cost-efficient manner, assuring further interconnectivity and security of energy supplies.

To develop hub-and-spoke projects that connect and integrate large scale offshore wind, it is necessary to evaluate the roles and responsibilities of project stakeholders over project phases and assets. A governance model prescribes that. However, given the novelty of the hub-and-spoke concept, a suitable and feasible comprehensive governance model, suitable specifically for hub-and-spoke projects, is yet to be defined.

Existing governance models, defined separately for offshore wind infrastructure, interconnection, and gas network development, typically can be categorised as centralised or decentralised. In a centralised governance model, system planning, ownership and operation is assigned to a national entity, usually a (gas or electricity) TSO. In a decentralised governance model, ownership of infrastructure assets is attained by a commercial entity.

While lessons can be learned from the existing governance models for offshore wind infrastructure, interconnection, and gas network development, hub-and-spoke projects have unique characteristics that are different from conventional projects. First, offshore wind transmission to shore and interconnection between countries are combined in a single project. In addition, hub-and-spoke projects combine both electricity as well as hydrogen infrastructure. Finally, conversion and storage of electricity is enabled on hubs to provide flexibility to the operators.

Recent publications by the European Commission describe forthcoming developments in offshore wind and hydrogen projects. While none of these publications clearly and undeniably endorses a centralised model over a decentralised model, the emphasis on integrated grid planning and strong oversight by the European Commission and ACER indicate the desire for national and European coordination in grid planning and development.

While a wide variety of governance models is possible, the North Sea Wind Power Hub (NSWPH) consortium provides an example of a governance model by extending the currently applied governance models in the relevant countries. As such, stemming from the currently applied governance models, the following allocation of roles and responsibilities could be envisioned:

- **System planning:** consortium of national electricity TSO and/ or gas TSO/ national state-owned entity to ensure coordinated and future proof infrastructure development.
- **Development** and **ownership** of the hub foundation
- **Ownership** and **operation** of transmission cables from hub to shore: national electricity TSO.
- **Ownership** and **operation** of interconnectors: shared between national electricity TSOs.
- **Ownership** and **operation** of hydrogen transmission pipelines: relevant national gas TSOs or network companies.
- **Ownership** and **operation** of other on-hub assets (such as energy storage and electrolysers): privately owned (e.g. commercial developers or gas network companies).

To realise a first hub-and-spoke project, national governments must take decisions on the exact configuration, ownership allocation of the hub foundation, and funding and cost recovery mechanisms. National governments need to form decisions on the allocation of responsibility for each element of the chain, the regulatory regime for interconnectors, funding and cost recovery for cross border cooperative projects and phasing of offshore grid build out. While some decisions require intergovernmental agreements (e.g. interconnectors), other decisions can be made nationally.

1 Introduction

The EU offshore wind strategy states that 60 GW of offshore wind capacity in 2030 and 300 GW in 2050 is realistic and achievable in European waters[1]. Reaching 300 GW by 2050 requires an unprecedented acceleration in offshore wind development. With such acceleration of scale, careful planning, economic use of resources and the available space are critical for the success of the strategy implementation. The North Sea Wind Power Hub (NSWPH) is developing a methodology for offshore wind infrastructure development that meets all these requirements. The consortium proposes a hub-and-spoke concept to (1) efficiently connect multiple offshore wind farms to shore (2) develop interconnection capacity between North Sea countries and (3) offer a platform for energy conversion. This novel approach calls for a re-assessment of roles and responsibilities in planning, ownership, and operation of assets. In other words, the hub-and-spoke concept calls for a new governance model.

Assets considered in a governance model for offshore wind farm development are the offshore wind farm itself the offshore substation and foundation, the transmission cables and the onshore substation. The governance model formally prescribes the roles and responsibilities of stakeholders in planning, development, and operation of these assets. For development of an offshore wind farm and the required infrastructure, relevant stakeholders usually include national governing bodies, offshore wind farm developers, infrastructure developers, infrastructure owners and infrastructure operators. Quite commonly in Europe, the national Transmission System Operator (TSO) is the offshore infrastructure developer, owner, and operator. Exceptions include the UK, where offshore wind developers usually develop both the wind farm and its connection to shore, and next, ownership of the offshore grid infrastructure is transferred to an independent Offshore Transmission Owner (OFTO).

Highligt

Unique complexities of a hub-and-spoke project calls for re-assessment of existing governance models.

For the development a hub-and-spoke project, several additional complexities can be identified. First, a hub may be used for realising interconnection capacity. As a result, more than one transmission system operator is likely to be involved. In addition, the integrated approach to electricity and hydrogen introduces additional assets to the governance model, such as hydrogen transmission, energy storage and electrolyzers. Lessons can be learned from existing governance models for offshore wind, interconnection, natural gas, and energy storage and elements of existing models can be used in developing a suitable model for the hub-and-spoke concept. However, unique complexities of a hub-and-spoke project do require a careful tailor-made design and assessment of additional roles and responsibilities.

[1] European Commission, An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future, 2020, Link

The topic of governance models is closely tied with other important topics pursued by NSWPH. Notably, the *Economic and Financial Framework* discussion paper[2], which will describe financing and cost recovery mechanisms for Hub-and-Spoke projects. Selecting appropriate financing and cost recovery mechanisms requires clarity on the roles and responsibilities of all stakeholders involved.

NSWPH has considered existing governance models and describes a suitable and feasible governance model for hub-and-spoke projects. This paper presents:

- Existing, conventional governance models for offshore wind, interconnection, natural gas, and energy storage; for Denmark, Germany, the Netherlands, and the UK[3]
- An overview of the latest trends and developments in governance models for offshore wind, hydrogen assets and infrastructure, and cross border infrastructure
- A description of a suitable and feasible governance model for a first hub-and-spoke project
- Decisions that need to be taken on a national and intergovernmental level
- Next steps for NSWPH

Highligt

The governance model topic is in close relation with the economic and financial framework topic, which requires clarity on stakeholder roles and responsibilities.

[2] North Sea Wind Power Hub programme, Economic and Financial Framework – discussion paper, under preparation.

[3] These countries (and Belgium) are of immediate interest to NSWPH for the development of a first hub-and-spoke project. Note that the offshore wind governance model for Belgium is similar to that of the Netherlands.

2 Existing governance models

A governance model prescribes the roles and responsibilities of stakeholders throughout the phases of a project. Defining a suitable governance model for a hub-and-spoke project benefits from a careful assessment of existing models for offshore wind, interconnectors, natural gas, and energy storage. Elements from the current governance models for various assets may prove to be useful for developing a governance model for hub-and-spoke projects. In this chapter, existing governance models for offshore wind, interconnectors, natural gas, and energy storage are described based on three building blocks:

- **The planning** building block describes who is responsible for system planning, including scenarios on future energy production and usage, and implications for further infrastructure investments
- **Asset ownership** describes who is the *majority* owner of the assets within the system; This responsibility typically includes pre-development, development, and construction.
- **System operation** relates to coordination of the system once it is operational, including operational planning, system and markets operations, and post operational tasks.

Project development is characterised by five major phases, as presented in Table 1. These five phases loosely correspond to the three building blocks of the governance model structure, as the majority ownership generally entails responsibility for pre-development, construction, and operation.

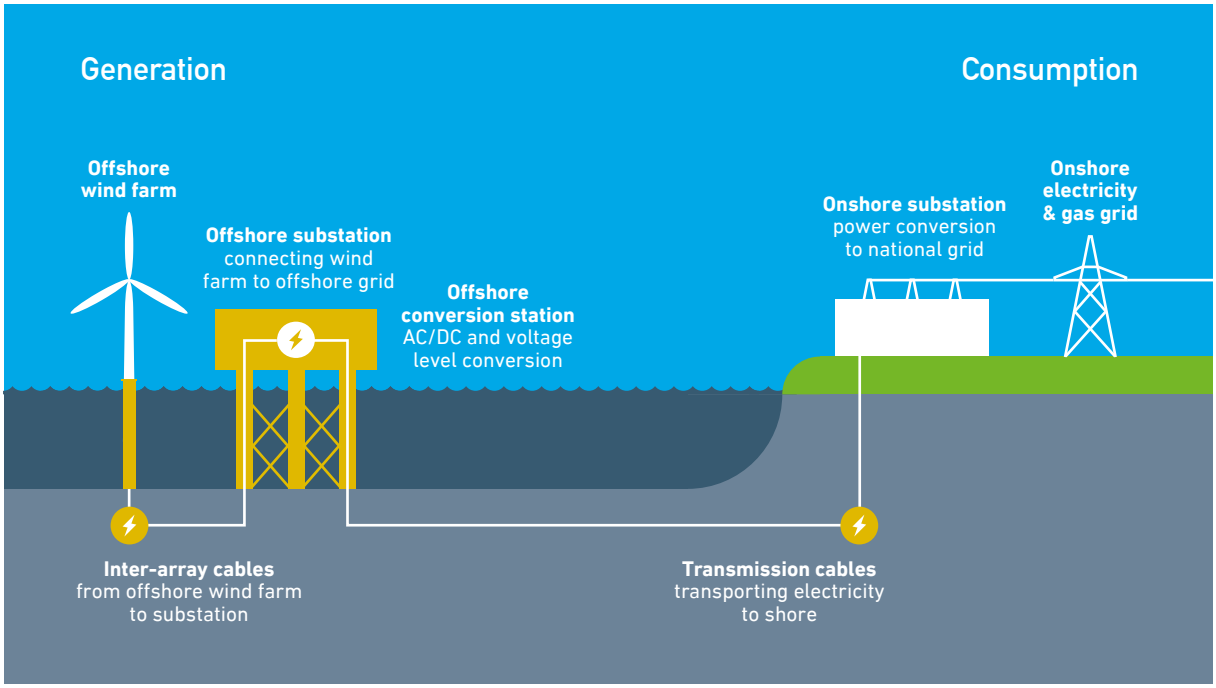
Table 1: Overview of project development phases

Project development phase	Description
Planning	Includes strategic energy system planning, studies on technical configurations, and initial project feasibility studies.
Pre-development	Preliminary technical studies to inform site selection and business case assessment.
Development	Final design, construction procurement procedure, environmental impact assessments (EIA), permit acquisition.
Construction	Physical construction and commissioning of various assets.
Operation	Asset and system operation and maintenance.

Offshore wind

While each offshore wind project has unique characteristics, the assets involved are typically the same. Figure 1 presents the types of assets deployed in the development of an offshore wind farm and transport of electricity to shore.

Figure 1: Overview of the assets in offshore wind development



So far, offshore wind farms (OWF) produce electricity, which is transported to shore via power cables. A possible future development could also include offshore power-to-gas (P2G) conversion. In case of offshore power-to-gas, hydrogen is either produced centrally on a platform or island or decentralised in wind turbines. However, as such projects have not yet been commissioned, there is no clear governance model yet defined for them. This paper will shed a light on possible governance models for a hub-and-spoke project, including the future possibility of offshore P2G conversion.

Highligt

There is no clear governance model defined for projects with offshore power-to-gas.

Allocation of roles and responsibilities in an offshore wind roll-out depends on the country of interest. Some countries (for example the Netherlands and Germany) favour a centralised approach, where national governing bodies have on a critical role in planning and pre-development of grid-connection. Other countries (for example the UK) have historically applied a decentralised approach, where commercial developers are responsible for developing the grid connection to shore. Denmark has recently used a decentralised approach in relation to a nearshore windfarm. It has not been concluded yet to what extend this will be the preferred approach for future projects. Actors in offshore wind development include national regulatory bodies, national TSO's and commercial developers and system owners. Figure 2 presents several representative governance models. In all cases, wind farm assets (wind turbine foundations and generators, inter-array cables between wind turbines) are developed, owned, and operated by commercial parties, and are therefore not presented in Figure 2.

Figure 2: Overview of centralised and decentralised governance models and their application in countries of interest[4,5]

	Planning	Ownership				System operation
	System planning	Inter array cables or pipelines	Offshore substation	Offshore converter station	Transmission cables or pipelines	Onshore substation	System operation
Centralised	TSO	OWF developer	TSO	TSO	TSO	TSO	TSO
	TSO	OWF developer	TSO	TSO	TSO	TSO	TSO
	TSO	OWF developer	OWF developer	TSO	TSO	TSO	TSO
	TSO	OWF developer	OWF developer > OFTO	OWF developer > OFTO	OWF developer > OFTO	TSO	TSO
Decentralised	TSO	OWF developer	OWF developer	OWF developer	OWF developer	OWF developer	TSO

In the *Netherlands*, the Ministry of Economic Affairs and Climate and the Dutch Enterprise Agency (Rijksdienst voor Ondernemend Nederland – RVO) take on a central role in planning and some aspects of pre-development. The TSO is responsible for development, ownership, and operation of the offshore- and onshore infrastructure. The Netherlands have thus adopted a strongly centralised governance model.

Germany has adopted a centralised approach, where the TSO is responsible for development and construction of transmission cables, as well as the offshore converter station. Until recently, the OWF developer was responsible for development of the offshore substation. In future projects, the offshore substation is omitted altogether, as wind farms will connect directly to the TSO converter platform with 66 kV inter array cables. The TSO is responsible for system operation.

The *United Kingdom* has adopted a decentralised governance model, where the offshore wind developer takes on the responsibility of development and construction of offshore transmission assets. However, ownership of these assets is not retained by the developer but rather transferred to an OFTO. This is a private party assigned through a competitive procedure by the Office of Gas and Electricity Markets (OFGEM). The transmission agreement must be validated by the TSO, responsible for the onshore grid connection point, as well as system operation.

Highligt

Where some countries favour a centralised governance model for infrastructure development (e.g. Germany and the Netherlands), other countries prefer decentralised (e.g .UK).

[4] The decentralised approach only has been used in Denmark in relation to one nearshore windfarm. All other windfarms are subjects to the centralised approach.

[5] For future projects in Germany, the offshore substation is avoided in the overall grid connection as inter array cables (66 kV) directly connect the wind farm to the TSO converter platform, see: TenneT, Energy, from sea to land, 2020, p.7, Link

Until 2020, *Denmark* made use of a centralised governance model, wherein the Danish Energy Agency was responsible for planning of the offshore infrastructure, in cooperation with the TSO. The TSO was given the task of construction, ownership and system operation. In 2018, a political agreement led to the adoption of a decentralised approach for post 2020 auctions. In the new governance model, so far applied only to a single nearshore wind farm, responsibility for the grid connection and even the first onshore substation lies with the offshore wind farm developer. System operation is retained by the TSO. In addition, Denmark knows an open-door procedure, where the offshore wind developer takes the initiative to establish an offshore wind farm in a predefined geographical area. However, system operation is still retained by the TSO. Note that for the development of energy islands, a public-private-partnership (PPP) will be applied, where the state will be the majority owner of the island, and private companies will take part in development of assets on the island.

Interconnectors

Interconnectors are cross-border power lines, allowing for electricity exchanges between markets, and thus providing enhanced security of supply for each of the interconnected markets. They also effectively provide socio-economic welfare value added by optimizing the overall dispatch of the electricity system within the interconnected markets. Given the multi-national nature of interconnection, governance of assets is subject to various regulatory regimes. Typically, the applied regulatory regime is a negotiated outcome between the relevant TSO's, Member States and national regulatory authorities (NRA). That means that an interconnector is exposed to two NRAs, and associated costs are often allocated on a 50-50% basis. Europe knows two types of interconnector ownership models: fully regulated and partially regulated (merchant). The former is most common in Europe, whereas the latter is most notably used in the UK. The major difference between the fully regulated and the merchant interconnector governance model is the source of income. In a fully regulated interconnector governance model, interconnection assets are part of the regulated asset base and therefore rely on a regulated income. An interconnection under a merchant governance model relies on a market-based income, obtained through congestion rents. Figure 3 presents the two governance models for interconnectors. The asset base is limited to a substation in each country and the cross-border transmission cable.

Highligt

For interconnectors, either a fully regulated interconnector governance model or a merchant governance model can be applied.

In the regulated interconnection governance model, planning is done by two TSOs of the countries involved, pending approval of both NRAs. Ownership (including development and construction) of the substation lies within the TSO of the respective country. Ownership and operation of the interconnector is the shared responsibility of the two TSOs involved. The main investment objective in the regulated governance model is to maximise social welfare. TSOs earn a regulated revenue through network charges, based on the cost of the development and operation of assets.

Figure 3: Governance models for interconnection

	Planning	Ownership			System operation
	System planning	**Substation 1**	**Cross-border cable**	**Substation 2**	**System operation**
Regulated	National TSO's	TSO nation A	National TSO's	TSO nation B	National TSO's
Merchant	Commercial developer	TSO nation A	Commercial developer	TSO nation B	Commercial developer

In the merchant governance model, a commercial party plans, owns (develops and constructs), and operates the interconnector. However, a TSO license must be obtained by the party operating the interconnection assets. Note that national TSOs may still be involved in the overall system planning, whereas the detailed technical design is the responsibility of the commercial developer. A possible construction is that the respective national TSOs form a subsidiary company to develop and own the interconnection assets. The main investment objective is to maximise private profits through the collection of congestion rents, while there are benefits to social welfare as well. National TSOs are still strongly involved, as the points of connection (substations) are owned and operated by the TSOs. In the UK, revenues to recover investments are regulated through a cap-and-floor regime. One example of an interconnector cable under the merchant governance model is the BritNed interconnector between the Netherlands and the United Kingdom. The cable is owned and operated by BritNed Development Limited, a joint venture of National Grid (UK TSO) and NLink, subsidiary of TenneT (Dutch TSO).

Natural gas transmission

Natural gas dependency in the European Union reached an all-time high of 89.5 % in 2019[6]. This means that nearly 90% of natural gas in the European Union must be imported. To transport the natural gas from production areas (such as Russia and Norway) to industrial and domestic end-users in the EU, an immense network of (cross-border) pipelines has been developed throughout decades.

Highligt

Governance of natural gas tranmission is similar to that of electricity transmission with a gas-TSO responsible for transmission infrastructure.

Governance of natural gas transmission in Europe resembles that of electricity transmission. For natural gas infrastructure, the gas-TSO is responsible for planning, ownership, and operation of gas transmission assets. For interconnection of natural gas throughout Europe, national TSOs of the respective countries are responsible for planning, ownership, and operation of the assets. Like electricity interconnection, cost is allocated to the respective TSOs based on mutual agreements between the TSOs, Member States and NRAs. Note that an interconnector can also be owned and operated by non-national TSO's, such as the BBL pipeline from the Netherlands to Great Britain. This requires an exemption from the tariff regulation under EU law, so the tariffs are negotiated between the pipeline operator and its customers.

[6] Eurostat, 2020, Link

3 Trends and developments

The previous section outlined two options for offshore wind- and infrastructure development and typical functionality of a centralised and a decentralised governance model. Existing literature[7,8] on the topic indicates that a centralised model is a better fit for future large-scale and cross-border infrastructure projects. Advantages for the centralised model include:

- TSO's are incentivised to consider the whole system perspective in planning and development, allowing future-proof development
- Better coordination between offshore wind development and onshore grid reinforcement is possible
- Adequate interconnector setup requires coordination between TSOs and NRAs, which is enabled by a centralised governance model

Highligt

There seems to be a preference for centralised governance model in Europe for multiple reasons.

National trends

As presented in the previous chapter, countries in Europe apply different varieties of centralised and decentralised governance models. However, there seems to be an overall preference for the centralised model for the reasons mentioned above. This premise is supported by recent policy developments in the UK, Denmark, and Norway. In the *UK*, the government and OFGEM have recently launched an ongoing review of the current model and associated governance for transmission assets[9]. In *Denmark*, a more hybrid approach is selected for the development of energy islands, which will be developed in a public-private partnership (PPP). The state will be the majority owner of the island, but private companies will take part in the development of the assets on the island. *Norway* recently announced that new offshore lease areas are to be appointed for offshore wind development after already opening 4.5 GW areas in 2020. The Norwegian government is now developing a regulatory framework for the development of profitable offshore wind projects. It is expected that Norway will adopt a centralised governance model, where national governing bodies and the TSO take on an active role in the planning and pre-development of offshore wind areas and transmission assets[10].

[7] Navigant, Connecting Offshore Wind Farms, 2019.
[8] Navigant, Offshore grid delivery models for Ireland, 2020.
[9] OFGEM, Review of GB energy system operation, 2021, Link
[10] OffshoreWind.biz, Norway to open new offshore wind lease areas, 2021, Link

European considerations

Several new policies and strategies for offshore renewable energy, hydrogen and infrastructure have been introduced by the European Commission, including:

- Offshore Renewable Energy Strategy[11]
- Staff Working Document on the Offshore Renewable Energy Strategy[12]
- Revised TEN-E Regulation
- EU Hydrogen Strategy[13]

These publications potentially have far-reaching implications for the European energy system and shed light on the major trends and expected developments in offshore wind and infrastructure development. In search of a suitable governance model for hub-and-spoke projects, it is essential to identify the expected direction or even preference for certain governance models.

Highligt

The emphasis on integrated grid planning and offshore wind development by the European Commission and ACER indicate the desire for national and European coordination in grid planning and development.

The *Offshore Renewable Energy Strategy* specifically notes integrated planning and development as a priority. TSOs are endorsed to continue building interconnectors for electricity trading and security of supply. The *Staff Working Document* further assesses the implications of future development options and unbundling of the energy market. It states a possibility to pursue several long-term options for meshed and integrated offshore grids, including an OFTO-inspired model, an Independent System Operator (ISO) model, and a model with a group of TSOs supported by a Regional Coordination Centre. For the short-term, enhanced cooperation between member state TSOs and regulators can be a suitable solution.

The Trans-European Networks for Energy, or *TEN-E regulation*, is a regulation that is focused on linking the energy infrastructure of EU countries. The revised TEN-E regulation endorses integrated grid planning and development. It also outlines the necessary next steps. On a European level, the revised regulation calls for an enhanced role for the European Commission and ACER to oversee the Ten-Year Network Development Plans (TYNDP, developed by ENTSO-E and TSO's). On a national level, the revised TEN-E outlines changes to permitting procedures and emphasises the need for a coordinated permitting procedure to ensure efficiency and enable investor certainty.

The *EU Hydrogen Strategy* does not provide endorsements for one model over another. However, the strategy does emphasize the need for full integration of hydrogen infrastructure in infrastructure planning.

While none of these publications clearly and undeniably endorses a centralised model over a decentralised model, the emphasis on integrated grid planning and strong oversight by the European Commission and ACER indicate the desire for national and European coordination in grid planning and development.

[11] European Commission, 2020, Link
[12] European Commission, 2020, Link
[13] European Commission, 2020, Link

4 A possible governance model for first hub-and-spoke project

A hub-and-spoke project combines aspects of offshore wind, gas, and interconnection infrastructure development. Where traditional offshore wind projects consist of power generation and transmission only, a hub-and-spoke project combines power production, conversion, and transmission over two separate commodities (hydrogen and electricity). In addition, the function of transmission cables today is either to bring offshore wind power to shore, or to provide interconnection capacity between two countries. A hub-and-spoke project combines these functionalities within the scope of one project. Finally, today the grid infrastructure for current and planned offshore wind farms are designed and developed for each individual wind farm. The hub-and-spoke concept allows for a modular approach where anticipatory investments in infrastructure allow for a phased build-out of multiple offshore wind farms. The novel approach of the hub-and-spoke project therefore calls for defining a new governance model to efficiently develop the future offshore wind system in the North Sea.

A governance model for hub-and-spoke projects must allocate roles and responsibilities across various assets (power, power-to-gas, hybrid infrastructure assets[14]), various phases of the project, and stakeholders across various countries. Other facets that need to be considered in defining a new governance model are:

- The speed of implementation,
- how the model supports realising synergies between onshore and offshore,
- whether the model allows for a gradual build out of the offshore grid, and
- the regulatory fit on a national and European level.

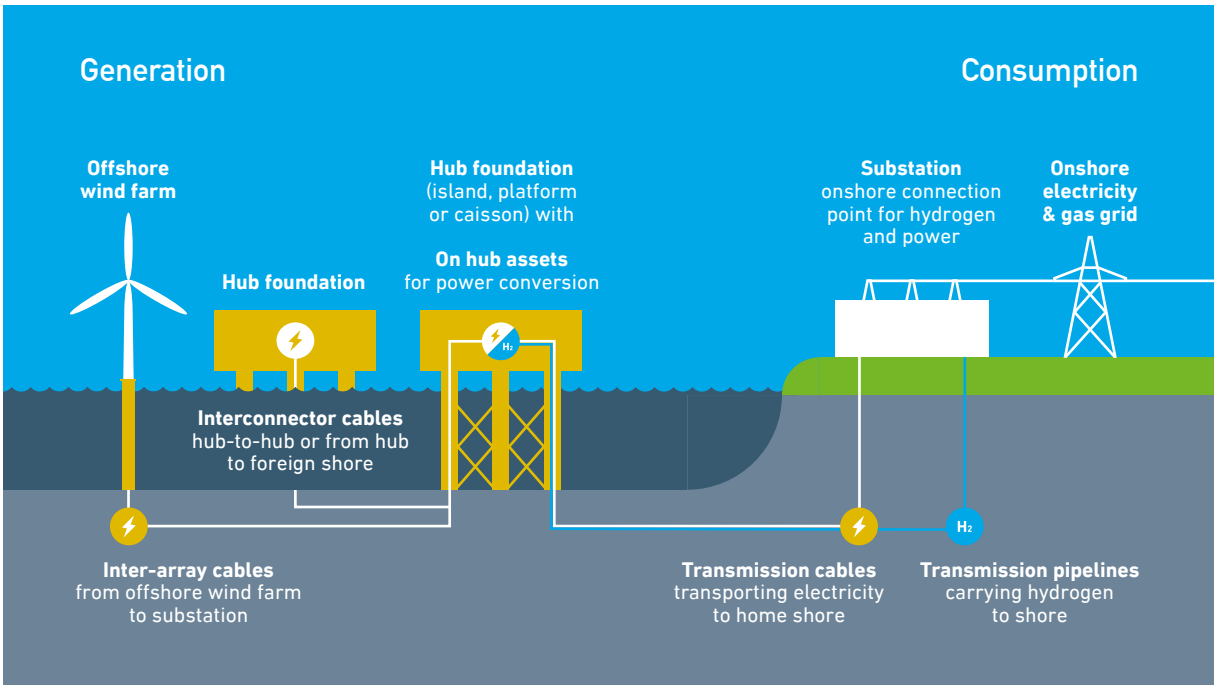
For those reasons, it is sensible to recycle specific aspects from currently applied governance models for offshore wind, natural gas, and interconnection infrastructure. In this section, a possible governance model for a hub-and-spoke project is described which is based on the currently applied governance models. Figure 4 presents the potential lay-out for a first hub-and-spoke project.

Highligt

Aspects of existing governance models can be reused to form a suitable and feasible governance model. This benefits implementation speed and regulatory fitness.

[14] Hybrid infrastructure assets refer to assets that serve a dual purpose: to connect wind farms to shore and to provide interconnection capacity between countries.

Figure 4: Overview of the assets for a hub-and-spoke project. Note that the on-hub assets may include AC/DC power conversion as well as power-to-gas assets.



Comparing this concept to the conventional wind farm lay-out in Figure 1, a few new elements are introduced. First, the conventional platform for the substation and HVDC transformer are replaced by a multifunctional hub. On the hub, there may be the same substation and HVDC components as well as power-to-gas or storage assets. The hub is connected to shore through transmission cables for electricity transportation and gas transmission pipelines in the case of offshore power-to-gas. Finally, individual hubs in different countries may be connected by interconnector cables, serving as interconnectors.

With these new (combination of) elements, new potential actors are introduced as well. Where a radial grid connection to shore is typically developed and owned by one TSO, e.g. a multi-functional island-based hub foundation is expected to include close coordination between two or more TSOs and additional governmental bodies. This means that more TSOs and/or governmental bodies are to be involved in the coordination, development and ownership of the infrastructure assets. In addition, the hubs can enable storage or power-to-gas assets to be placed offshore, with the potential advantage of cable length and pipeline capacity optimisation. These types of assets can generally not be owned and operated by TSOs, requiring participation of private entities, such as commercial developers or network companies, in the development and ownership of on-hub assets.

Highligt

Due to the multi-national character of a hub-and-spoke project more TSOs will be involved in the coordination and operation.

A possible governance model

Multiple functions of a hub-and-spoke project and the overall trend towards co-ordination and integration benefit from a centralised governance model. Figure 5 presents a potential governance model for a first hub-and-spoke project.

Figure 5: Suitable and feasible governance model for first hub-and-spoke project

	Planning	Ownership					System operation
	System planning	**Hub foundation**	**Offshore transmission cables (hub to shore)**	**Interconnector cables (hub to hub or hub to foreign shore)**	**Hydrogen transmission Pipelines**	**Offshore storage or PtG assets**	**System operation**
Reference model	Consortium of TSOs	National electricity TSO and/ or gas TSO/ national state-owned entity	National electricity TSO	Consortium of electricity TSOs	National gas TSO(s) and/or gas network company	Privately owned (commercial developers and/ or gas network companies)	National TSOs

Currently, there is no formal responsibility for *system planning* allocated to one specific entity. A hub-and-spoke project knows many interfaces between national gas and electricity TSOs, so system planning, in this example, could be allocated to a consortium of national TSOs, each considering their respective national interests and targets while collectively working towards an optimum configuration.

Highligt

System planning seems a good task for a consortium of TSOs as it requires insights in national interest and targets for electricity and hydrogen.

A hub-and-spoke project combines many different assets in, therefore, *development and ownership* of the respective parts is split between various parties. The hub foundation is the key component, as it quite literally is the centre of all activities. A suitable allocation of responsibility for the development and ownership for the hub foundation depends strongly on the functionality and the type of foundation for the hub, for which there are several possibilities. E.g. an all-electric platform-based hub connects wind farms to shore and can connect to other hubs providing interconnection capacity. For such a hub, ownership of the foundation and of power infrastructure components could be naturally assigned to the national electricity TSO when extending the currently applied governance models. On the other hand, ownership of a hub with only gas transmission infrastructure components could be more naturally assigned to the national gas TSO or gas network company. In case policymakers are opting for a multifunctional hub which also includes non-TSO assets such as power-to-gas and storage, full ownership of the hub by the national TSOs does not seem logical, since these activities are not part of the legal task of the national TSOs.

Highligt

Depending on the functionalities of the hub, either a gas or electricity TSO or other national body can best own the hub.

For a multi-purpose hub with an island based foundation, such as Danish energy islands, a national governing body is expected to take ownership of the island and a similar approach can be expected for an energy island in the Dutch water[15]. When the currently applied governance models are extended for a hub-and-spoke project, offshore transmission cables to the shore can naturally be owned, developed, and constructed by the national electricity TSO. For gas infra-

[15] Rijksoverheid, Ontwerp Programma Noordzee 2022-2027, Link

structure to the shore, ownership could, as a target model, then in the same way be assigned to the relevant gas TSO, however in a transition phase development and ownership responsibilities can also be allocated to e.g. network companies. Regarding the development and ownership responsibility of interconnection cables between hubs, a natural split between the respective national electricity TSOs could be envisioned, similar to the centralised governance model for interconnection. Finally, on-hub assets such as storage or power-to-gas installations.

As a possibility, system operational responsibilities of the electrical and gas infrastructure of a hub-and-spoke project can be the responsibility of national TSOs. In this example, the national TSOs of the home country operate transmission cables and pipelines from the hub to the shore. Interconnection cables are operated on a mutual basis between the respective national TSOs, similar to the current operation of interconnectors owned and operated by existing TSOs. The responsibility of efficient balancing and system operation consequently lies with the TSOs. System operation on a national level benefits from regional coordination through Regional Coordination Centres (RCCs)[16]. As currently in the onshore domain, RCCs have regional coordination responsibilities, including facilitation of regional sizing, coordination of the interfaces between system operation regions.

Highligt

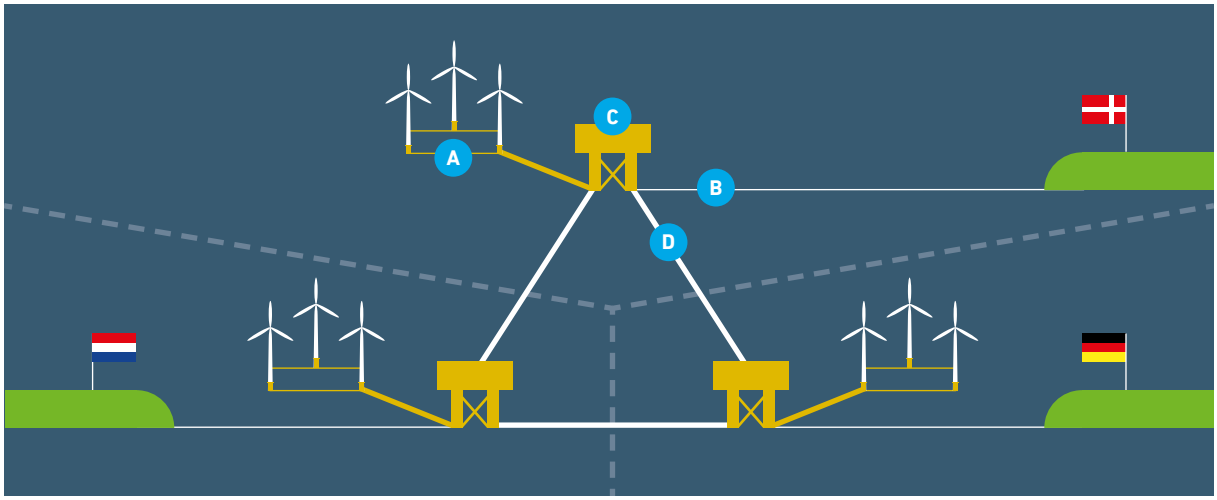
System operation of a hub-and-spoke project can be the responsibility of the national TSOs similar to the current approach.

Table 2: Application of the described model to system components (see also Figure 6)

Component	Description	Governance
A	Offshore wind farm	Planned, owned and operated, by a commercial developer.
B	Transmission cable to the shore	Planned, owned, and operated by the TSO
C	National hub	Planned, owned, and operated by (a) national TSO(s) or a governing body.
D	Interconnection cable*	Planned, owned, and operated by the TSOs of the respective countries

* Interconnectors can also include hub to shore transmission cables, in case they are cross-border.

Figure 6: Conceptual representation of offshore energy hubs in the Netherlands, Denmark, and Germany



[16] ENTSO-E, System Operation & Governance, 2021, Link

Application of the possible hub-and-spoke governance model

Throughout the conceptual analysis, the currently applied governance models for conventional infrastructure assets were used as a starting point. However, to make this more practical, in this section a hub-and-spoke governance model is applied to a possible configuration of an interconnected hub-and-spoke project to identify where national and intergovernmental decisions need to be taken, while also elaborating on the potential upsides of such an applied governance model. Figure 6 presents a potential configuration of national interconnected hubs, and Table 2 presents the governance of individual components. The described model does not deviate significantly from existing governance models for offshore wind transmission and interconnection. This allows for enhanced speed of implementation, as stakeholders are familiar with the role assigned to them.

Highligt

A hub-and-spoke governance model which is close to existing governance models for offshore wind transmission and interconnection allows for enhanced speed of implementation, lower project CAPEX and compatibility with national and EU policies.

System planning optimization, across the onshore and offshore domain increased security of supply and economic efficiency in the development of the hub infrastructure are key advantages of the described model. Cost comparison studies show that application of a centralised governance model results in lower CAPEX per in-stalled capacity of offshore wind[17]. TSOs generally have a lower cost of debt than private actors and are more capable of taking interface risks. In addition, a governance model where the TSO takes the lead in infrastructure development is beneficial for competition in offshore wind development as developers can rely on the experience and reliability of TSOs to realise the critical infrastructure.

Further advantages of the described hub-and-spoke model include the fit with current and expected national and EU policies. The centralised model facilitated the Dutch and German governments in reaching their offshore wind targets in cost-efficient manner. The UK has recently initiated a review of the OFTO-governance model due to inefficiencies in the developer-led (decentralised) governance model, and Denmark recently agreed to TSO ownership of transmission assets for the energy islands. The described governance model is seen as fit for future in Europe, given its focus on regional cooperation and coordination enabling future large-scale roll-out and cross border collaboration.

Finally, advantages in the techno-economic impact include the speed of implementation and coordination between project development phases. The described model does not require new legal entities to develop and own infrastructure. Ownership and contractual principles between TSOs known from interconnection development apply to the hub-and-spoke asset as well. The described governance model encourages planning and coordination between offshore generation and onshore grid reinforcements. Given the responsibility throughout all phases of project development, the described model enables TSOs to optimize the total lifecycle costs in combination with the optimization between new infrastructure and operational costs, including congestion management.

[17] DNV-GL, Cost of offshore transmission, 2019, Link

5 Conclusions and recommendations

Conclusions

Hub-and-spoke projects require a tailored governance model as new types of assets and international collaboration are introduced. Elements from existing models for offshore wind farms, interconnectors, and natural gas infrastructure can be combined to develop a suitable governance model for hub-and-spoke projects, however alternatives could be explored. Literature, national developments, and European strategy suggest that a centralised approach, where national entities and TSOs take the lead in planning, ownership, and operation of infrastructure assets, could be a suitable approach to ensure regional cooperation and coordination. This paper describes a possible governance model where system planning can be done by a consortium of gas and electricity TSOs in close collaboration with national governments to incorporate national ambitions regarding the roll-out of offshore wind. In addition, the described model outlines how development, ownership and operational responsibilities can be allocated while having in mind (1) overall system planning and design optimization, (2) economic efficiency, (3) fit with current and future policies and (4) speed of implementation.

Highligt

A governance model for a hub-and-spoke model can be based on existing models, which show a trend towards the centralised approach.

National and intergovernmental decisions

While the described model stays close to existing models, decisions still need to be taken by the respective countries on the novel aspects of hub-and-spoke projects. Here, two timelines are considered: realization of the first hub-and-spoke project and further expansion into a meshed offshore grid.

For realization of the first hub-and-spoke project, national governing bodies must decide on the aspects listed below.

- **Configuration** of the first hub and connection to the shore. For offshore wind development plans beyond 2030, governments are currently assessing potential wind areas, infrastructure options, and timing. A hub-and-spoke configuration allows for a phased build out of the offshore grid, but requires decisions on the capacities, configuration, infrastructure routing.
- **Ownership allocation** of the hub foundation. Suitable ownership models depend on the configuration for the first project, as well as the envisioned final configuration and the type of foundation. As described, an all-electric platform-based hub could be most naturally owned and developed by an electricity TSO, whereas inclusion of gas transmission infrastructure could call for shared ownership between electricity and gas TSOs. When considering multi-functional or island based solutions for the hub, a dominant role for the various governments is expected. More specifically, a public-private partnership (as chosen for the Danish energy islands) may be considered for island based solutions.
- **Funding and cost recovery** of infrastructure assets. Infrastructure and interconnection assets in the described governance model will mostly fall under the regulated asset base of TSOs. However, national regulatory authorities will need to assess the economic feasibility and incentives for development of other important assets such as wind farms, storage facilities, and power-to-gas installations.

For developments towards a meshed offshore grid for interconnection and offshore wind integration, national governing bodies must decide on spatial planning for potential additional hubs. In case offshore hydrogen production proves to be beneficial, either centrally on a hub or decentralised integrated in wind turbines, governments must consider adapting offshore wind policy measures to be transferable to hydrogen production.

Governments of the engaged countries must cooperate to ensure efficient development of an interconnected offshore grid. For realization of the first hub-and-spoke project, intergovernmental decisions must be taken the following aspects.

- The **allocation of system planning** responsibility. There's no formal allocation of this responsibility in cross-national projects. For a hub-and-spoke project, the system planning role could be undertaken on by a consortium of national (electricity and gas) TSOs to ensure regionally coordinated planning while safeguarding national renewable energy and societal welfare objectives.
- **Regulatory regime for interconnectors** between national hubs. National regulatory authorities need to decide on cost and benefit allocation between the respective TSOs developing and operating the interconnection assets. More specifically, a commercial model for the possible interconnections needs to be considered, requiring more detailed discussions on commercial arrangements.
- **Funding and cost recovery** for cross border cooperative projects. A hub-and-spoke project requires novel approaches to infrastructure development across countries. Here, EU funding (such as the EU Renewable Financing Mechanism or Connecting Europe Facility) or, alternatively, separate commercial agreements between Member States can play an important role in funding and cost recovery of the preparatory work as well as project development.
- **Phasing** of offshore grid build out – modularity is one of the benefits of the hub-and-spoke concept. Therefore, in developing the first step, national governing bodies must agree on modularity of the design and the phases towards the final configuration.

Expanding from the first hub-and-spoke project to an international, meshed offshore grid requires decision making on an intergovernmental level. Collective decisions are required to define the desired lay-out of the international offshore grid. In addition, cooperation with countries that employ other governance models for offshore infrastructure development and interconnectors (i.e. the UK with the OFTO model and merchant interconnectors) requires decision making on a case-by-case basis.

Next steps for the consortium

Given the novelty of hub-and-spoke project concepts, a suitable governance model has yet to be defined. In this paper, NSWPH presents a governance model concept for a first hub-and-spoke projects. The described governance model will be further investigated regarding its implications for specific case studies (configurations, capacities, and layout of envisioned hub-and-spoke projects). In parallel, the consortium is working on developing an economic and financial framework, where the impact of the governance model on funding and cost recovery are assessed.

Highligt

While the governance model does not have to deviate much from existing models, decisions still need to be taken by the respective countries on the novel aspects of hub-and-spoke projects.

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