Hertie School
of Governance

# Large Infrastructure Projects in Germany
## Between Ambition and Realities

Working Paper 4

# Offshore Wind Power Expansion in Germany
## Scale, Patterns and Causes of Time Delays and Cost Overruns

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**Table of Contents**

**List of Abbreviations**

4CO: 4C Offshore Ltd.

AC/DC: Alternating Current/Direct Current (electricity transmission)

BDEW: Bundesverband der Energie- und Wasserwirtschaft (Business Council for Energy and Water)

BARD: Bekker-Arngold-Russland-Deutschland (Offshore Wind Park)

BMUB/BMU (until 2013): Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Federal Ministry for Environment, Nature Conservation, Construction- and Reactor Safety)

BMWi: Bundesministerium für Wirtschaft und Energie (Federal Ministry for the Economy and Energy)

BNetzA: Bundesnetzagentur (Federal Network Agency)

BSH: Bundesamt für Seeschifffahrt und Hydrographie (Federal Ministry for Shipping and Hydrography)

CEER: Council of European Energy Regulators

DWG: Deutsche Wind Guard

EC: European Commission

EEG: Erneuerbare Energien Gesetz (Renewable Energy Act)

EESI: Environmental and Energy Study Institute

EEZ: Exclusive Economic Zone

EIB: European Investment Bank

EnBW: Energie Baden-Würtemberg AG

EnWG: Energiewirtschaftsgesetz (Energy Economy Act)

EPC: Engineering, Procurement and Construction

EU: European Union

EWEA: European Wind Energy Agency

FIT: Feed-in-tariff

IPAA: Infrastrukturanpassungsbeschleunigungsgesetz (Infrastructure Planning Acceleration Act)

IWR: Internationales Forum Regenerative Energien

GHG: Greenhouse Gas

GWEC: Global Wind Energy Council

KfW: Kreditanstalt für Wiederaufbau (Credit Agency for Reconstruction)

KPMG: Inititials of Klynveld Main Goerdeler and Peat Marwick

TSO: Transmission System Operator

OWF: Stiftung Offshore-Windenergie (Offshore Wind Foundation)

OWP: Offshore Wind Park

OWT: Offshore Wind Turbine

RWE: Rheinisch-Westfälisches Elektrizitätswerk AG

PWC: PricewaterhouseCoopers

WAB: Windenergie Agentur Bremerhaven

WPD: WPD AG

## Introduction

Germany wants offshore wind energy to become a key driver of its *Energiewende* (energy transition), a transformational 'megaproject' intended to substantially re-engineer Germany´s national energy infrastructure. The German government envisioned offshore wind delivering 15% of electricity consumption by 2030, so it is crucial for the *Energiewende* to succeed (Bundesregierung, 2010).

Megaprojects are generally difficult to manage. Bent Flyvbjerg (2014, p. 6) defines megaprojects as "large-scale, complex ventures that typically cost $1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people." Such projects often take longer and cost more than initially planned. Offshore wind power expansion, as a national policy, is such a megaproject. An individual offshore wind park (OWP) is a megaproject as well, as a 300-400MW park typically costs €1.5 billion. Analyzing offshore wind power expansion in Germany contributes to lessons for the overall management of the *Energiewende*.

The aim of this study is to analyze the scale, patterns, and causes of cost overruns in OWPs. The result is a 20% average cost overrun for construction and installation of finished OWPs in Germany—low compared to other large-scale energy projects. However, what led to further additional costs is the regulated connection of the OWPs to the grid. This is the result of the separation of responsibility for construction of the OWP between the wind park developer and the transmission system operator (TSO), which led to governance problems. Time delays in grid connection, 13 months on average per park, led to a compensation of forgone revenue to the wind park developers, paid by an additional surcharge ("Offshore-Haftungsumlage") to consumers. These additional surcharges cost more than €1 billion for the eight existing OWPs finished by the end of 2014 (Netztransparenz, 2013; 2014a).

## Research Objective and Motivation

The key driver of offshore wind energy development is the political will to develop a "greener" energy infrastructure, currently at a higher cost than other sources of supply. As a carbon-free renewable source, OWPs are promising contributors to greenhouse gas (GHG) emission reductions. But offshore wind power is currently not market-competitive: in 2014, its cost per unit of power generation in the

European market was more than double the cost of onshore wind (Energy Intelligence, 2014).[1] To boost offshore wind development, Germany has feed-in tariffs (FIT) and set the target of 10GW of installed capacity in 2020 and 25GW in 2030. However, the development of installed capacity went slower than expected. Newspapers reported cost overruns and time delays and criticized the expansion plan (Die Zeit, 2012). In 2012, only 280MW were installed and the government revised its targets to 6.5GW in 2020 and 15GW in 2030.

The motivation of this study is to identify present problems of planning and implementing large projects in public policy, which contributes to better planning and project delivery in the future. To study the impact of public policy, this study analyzes developments in the wind offshore industry. A study on the scale, patterns and causes for the time delays and cost overruns of German OWPs is necessary to draw lessons for German energy and climate policy, and, more generally, development of offshore wind power, management of national energy infrastructure and industrial policy. Further, this study adds value to the existing literature by examining complex interaction processes between public and private stakeholders in energy infrastructure projects, as well as key trade-offs in energy and climate policy.

*Literature Review*

Megaprojects are generally complex and difficult to manage. Flyvbjerg et al. (2003), looking at 258 large-scale infrastructure projects, found that 9 out of 10 were completed with significant time delays and cost overruns. Merrow (2011), examining 318 private sector energy megaprojects, found that costs in oil and gas projects are on average 33% higher than originally estimated in 78% of the cases. Ansar et al. (2014) looked at 245 hydropower projects and found an average cost overrun of 96%. Sovacool et al. (2014) found a 117% average cost overrun for nuclear power plants and much lower cost overruns for thermal plants (13%), wind farms (8%), transmission lines (8%) and solar facilities (1%). The reference classes for electricity with the highest sample size are listed in Table 1. Flyvbjerg et al. (2003, 2007, 2009) showed that projects have time delays and cost overruns for technological reasons (e.g., interface complexity), psychological reasons (e.g. “optimism bias”) and political-economic reasons (e.g. interest conflicts, strategic deception).

[1] $179/MWh for offshore compared with $95 for gas, $93 for coal and $83 for onshore.

**Table 1: Reference classes for electricity infrastructure projects**

| Project Type | Sample Size | Average Cost Overruns (in %) | Average Time Overruns (in %) |
|---|---|---|---|
| **Hydropower** | 245 | 96 | 44 |
| **Nuclear reactor** | 180 | 117 | 64 |
| **Thermal plant** | 36 | 13 | 10 |
| **Wind farm** | 35 | 8 | 10 |
| **Solar facility** | 39 | 1 | 0 |
| **Transmission** | 50 | 8 | 8 |

Sources: Ansar et al. (2014), Sovacool et al. (2014)

Time delays and cost overruns in OWPs have been insufficiently analyzed, and there is no reference study for Germany. KPMG (2010) has analyzed differences in regulatory regimes in European nations. Studies both by PWC/WAB (2012) and Prognos/Fichter (2013) have attested offshore wind power in Germany a great potential and show pathways for cost reduction. Reimers et al. (2014) have shown empirical evidence for learning curve effects in offshore wind development. Sovacool et al. (2014) have found an 8% average cost overrun for the 35 wind farms analyzed. They found that cost overruns in wind parks are low because of technological standardization and quick construction lead-times. Yet, they do not distinguish between onshore and offshore wind projects. Reports on offshore wind development in Germany have not examined time delays and cost overruns and have ignored the impact of the cost of grid construction on the cost per unit of power generation. They have not addressed the interface problems of the regulated grid connection and the private offshore wind industry. This is the key contribution of this study, showing that there was a specific governance problem.

## Methods and Data Selection

The case of this study is offshore wind expansion in Germany. This case entails specific policies and industrial development. The unit of analysis of this study are OWPs in Germany. Currently, eight OWPs are operational, five under construction and 29 are planned or proposed. The study selected the eight OWPs currently operational as a sample.[2] For those, all relevant decisions have been made (e.g. grid

[2] An OWP is operational as soon as the offshore wind turbines (OWTs) are installed, are connected to the grid and produce electricity.

connection, turbine type) and the observable issues have already occurred or not occurred, which is not the case for OWPs currently under construction, planned or proposed. Further, the OWPs are the result of the examination of the current policy, while the future OWPs are potentially subject to a different one. To learn more about specific patterns and causes, this study further looked at four OWPs (Alpha Ventus, BARD 1, Nordsee Ost and Riffgat) in-depth. The selection of in-depth case studies represents a diversity of differences in size, location, and potential governance issues.

**Table 2: Key data on finished OWPs in Germany**

| Offshore wind park name | Capacity (MW) | Start of construction | Planned end of con-struction | Time delay (months) | Planned cost (million €) | Final cost (million €) | Cost overrun (%) |
|---|---|---|---|---|---|---|---|
| Alpha Ventus | 60 | Aug-2007 | 2009 | 12 | 190 | 250 | 32 |
| Baltic 1 | 48 | Jul-2009 | 2010 | 6 | 200 | 200 | 0 |
| BARD 1 | 400 | Jun-2009 | 2013 | 24 | 1500 | 2900 | 93 |
| Nordsee Ost | 295 | Jul-2012 | 2013 | 18 | 1000 | 1130 | 13 |
| Borkum Riffgat | 108 | Sep-2012 | 2013 | 6 | 480 | 480 | 0 |
| Global Tech I | 400 | Aug-2011 | 2014 | 12 | 1600 | 1800 | 13 |
| Meerwind Süd/Ost | 288 | Sep-2012 | 2013 | 18 | 1200 | 1300 | 8 |
| DanTysk | 288 | Dec-2012 | 2014 | 6 | 1000 | 1000 | 0 |
| | | | | Ø 13 | | | Ø 20 |

Source: OWP database

This study examines the governance setup of energy infrastructure project planning in Germany, which is a dynamic interaction process between various private (investors, TSOs, suppliers) and public actors. The study refers to the governance setup as "semi-private," because wind park construction and power generation is private, supported by FITs, while the grid construction is regulated.[3] The outcome-variables

[3] This study uses the term „semi-private“ and not „semi-public“ because the feed-in-tariffs are an incentive-based policy for private developers. No private developer is obligated to construct an OWP.

are time delays and cost overruns. A cost overrun is the difference between the initially planned costs at start of construction and the cost at the end of construction **(**Cantarelli et al., 2012).

*Data Sources*

This study uses a database, containing 42 OWPs, classified according to their name, location, wind park developer, TSO, operational status, distance to shore, water depth range, capacity, number of turbines, turbine type, converter platform, start of construction, planned end of construction, time delays in months, forgone revenue estimate, planned cost at start of construction and actual cost at the end of construction. The data is from the Windenergie Agentur (WAB) and the 4COffshore Ltd. (4CO). Supplementary sources are company publications, newspaper articles and interviews. Data on German offshore wind energy capacity development is from Deutsche Wind Guard (DWG), and European capacity development from the European Wind Energy Agency (EWEA). Further, the study uses academic articles, and reports by consultancies, official institutions or think tanks, as well as eight interviews in person, over the telephone or email with representatives of the government and the industry, including wind park developers, TSOs, supplier companies, and consultants.

## Policy Context

*European Energy Policy*

The European Union (EU) has ambitious renewable energy expansion targets and wants offshore to become a key pillar of its future energy system. The European Commission's (EC) "2020 climate and energy package" emphasizes the "20-20-20 target," 20% reduction in GHG emissions, a rising share of energy consumption from renewable sources by 20% and a 20% improvement in energy efficiency compared to 1990-levels (EC, 2014). In its 'Communications' document in 2008, the EC announced that "offshore wind can and must make a substantial contribution to meeting the EU's energy policy objectives through a very significant increase - in the order of 30-40 times by 2020 and 100 times by 2030 - in installed capacity compared to today." (EC, 2008) This would equal 40GW installed by 2020, 4% of the projected EU electricity demand, and 150GW by 2030, 14% of the demand. The 2008-'Communications' document identified project finance and grid planning as the key challenges facing the offshore wind industry and recommended various regulations and initiatives to boost industrial development (EC, 2008). According to the 2012-'Communications' document, the European Investment

Bank (EIB) had lent €3.3 billion between 2005 and 2011 for offshore wind projects and will sustain the effort to meet the targets (EC, 2012).

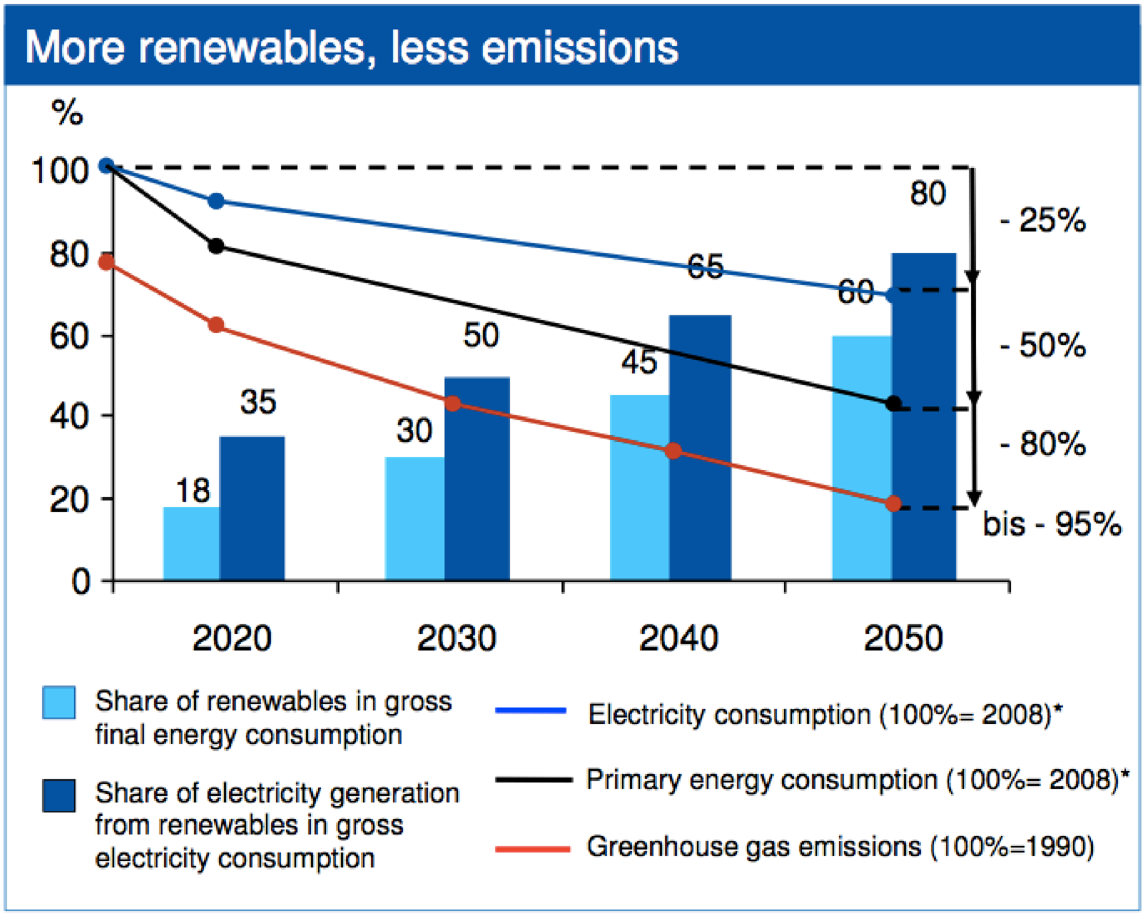
Europe is the world market leader in offshore wind capacity with a current 92% share (EWEA, 2015. GWEC, 2015). In 1991, DONG Energy (then: DONG) built and installed the world´s first OWP, Vindeby, off the shore of Denmark, with a capacity of 5MW. The UK, the current market leader in Europe, installed its first OWP in 2000 and pursued active policies to enable sector growth (EESI, 2010). By the end of 2014, 11 European nations had installed and connected a total of 74 OWPs to their grids, equivalent to 2,488 OWTs and about 8GW capacity (EWEA, 2015). Germany ranks third in Europe with a currently installed capacity of about 1GW, 13% of total offshore wind capacity, after Denmark (1.3GW, 16%) and the UK (4.5GW, 56%). China had ambitious targets to build 5GW by 2015 and 30GW by 2020, but had installed only 429MW by the end of 2013 and revised its target to 2GW (Bloomberg, 2014).

The key issue that affected development of offshore wind energy in Germany was the "unbundling" decision. Because the EU saw power supply as driven by quasi-monopolistic vertically integrated energy companies, it enacted regulations to separate them. With the "Third Energy Package" in 2009, the EU defined the requirements to separate power systems into supply, generation, distribution and transmission (CEER, 2013). This significantly impacted the German electricity market, which was dominated by the "big four" utility firms (E.ON, EnBW, Vattenfall and RWE). The "unbundling" decision was the origin of the "black box" system in Germany between wind park developers and TSOs.

*German Energy Policy*

Germany has even more ambitious targets than the European Commission and intends to substantially re-engineer its national energy infrastructure. Graphic 1 depicts Germany's plans to shut down all nuclear power plants by 2022, reduce greenhouse gas (GHG) emissions by 80% by 2050, increase the renewables' share of power generation to 35% in 2020, 80% in 2050, and increase the renewables' share of total energy consumption to 18% in 2020, 60% in 2050 (BMUB, 2014). In total, Germany plans that 15% of power generation will be made up of offshore wind in 2030.

**Graphic 1: Targets of renewable expansion and emission reduction in Germany**




Source: RWE Innogy (2012)

*Legal Support Scheme*

Germany has support schemes, the “Erneuerbare Energien Gesetz” (EEG) and the “Energiewirtschaftsgesetz” (EnWG), which are intended to support the development of the renewable energy industry by incentivizing producers with FITs. Because offshore wind is not market-competitive with other sources of power generation, and the original FITs were initially too small, the government discussed amendments to increase them in the early 2000s. A government representative recalls: “(…) one of the main issues of the strategy were the subsidies, which were not enough for offshore to be economically viable. Second was the grid connection, which the government later decided to guarantee as additional support.” (Interview 013115) The government enacted five amendments to the EEG in

2000, 2004, 2009, 2012 and 2014 (see Table 3), which increased the FITs and introduced new models, intended to make OWPs profitable and incentivize learning.

*Ambitious Expansion Targets*

"Our targets were too ambitious in the beginning," a government representative said. "The key mistake was the flawed assumption that 'wind energy is wind energy.' Many people thought offshore wind would be the same as onshore at sea (…). But offshore was a completely different industry (…)." (Interview, 013115) In 2002, a government strategy paper set a non-binding target of 0.5 GW by 2006, 2-3GW by 2010 and 25GW by 2030 (KPMG, 2010). But only about 100MW were installed in 2010. In the wake of the 2009-EEG amendment, the government took more concrete strategic steps and set the target of 10GW by 2020 and 25GW by 2030 (EEG, 2009). But by the end of 2011, the grid connection problem proved more severe than expected. In the 2014-EEG amendment, the government revised its targets from 10GW to 6.5GW in 2020 and from 25GW to 15GW in 2030 (EEG, 2014). According to a government representative, the key issues were cost control and transparency. "Our intention was to pass two critical stages, collect experience and manage expectations." (Interview, 013115)

**Table 3: Timeline for offshore wind development, Infancy Period (1997-2009)**

| **Infancy Period (1997-2009)** | |
|---|---|
| **2000** | <u>EEG Amendment</u><br>• Explicit offshore feed-in tariff of 9.1 c/kWh for 9 years in the EEG |
| **2001** | BSH issues the first construction permit for an OWP |
| **2002** | Government adopts offshore strategy with non-binding target of 2-3GW until 2010 and 25GW by 2030 |
| **2004** | <u>EEG Amendment</u><br>• Differentiated offshore feed-in tariff of 9.1 c/kWh for 12 years<br>• Extension depending on distance to shore and water depth |
| **2006** | Infrastructure Planning Acceleration Act (Infrastrukturplanungsbeschleunigungsgesetz) |
| **2007** | DOTI consortium starts construction of pilot-OWP Alpha Ventus |
| **2009** | Area designation act determines the EEZs of the Baltic and North Sea |

Sources: Falk and Wagner (2012), Offshore-windenergie.net (2015)

In the infancy period, companies started small offshore wind projects and the government began defining the regulatory framework. A few small German companies intended to replicate their experience in onshore wind at sea. First experiences with offshore wind power existed in Denmark and the UK, where the first commercial OWPs fed electricity into the grid (Interview, 011415). As the German government supported the development of renewable sources of energy, it made decisions on the regulatory questions of the maritime zone, the EEG feed-in tariffs and the grid connection. Under the 2006 IPAA, German TSOs were obliged to connect OWPs under construction to the grid before 2015. But the regulation was unclear because the TSOs wanted to make grid connection commitments contingent on secured financing (KPMG, 2010).

But banks or big utility firms, who could finance capital-intensive projects, needed a secured grid connection before lending large sums of money – a hen-egg problem. Due to environmental lobbying, state regulators decided the wind park developers had to bundle their grid connections, obliging Alpha Ventus to lay them at the junction of the island Norderney (Interview, 011415). But, as a former engineer of a wind park developer recalls, the companies involved in the consortium for Alpha Ventus could not agree on the financing of the grid connection cluster (Interview, 011415).

As a reaction, the government decided Tennet TSO GmbH should build the clusters and connect the transmitters to the onshore grid. To clarify the regulation, the Federal Network Agency (BNetzA) published a position paper (see KPMG, 2010). A consultant said: “If a company decided to build a wind park, there was little central planning involved (…). Other than in Denmark, where offshore wind farms were planned centrally and tendered by the Danish Energy Agency, what followed in Germany was a run on new project developments in the German bight.” (Interview, 011415) Expecting guaranteed grid connection, wind park developers staked maritime claims and started construction.

**Table 4: Timeline for offshore wind development, From Gold Rush to Gridlock (2009-2011)**

| | |
|---|---|
| **2009** | <u>EEG Amendment</u><br>• Increase of the feed-in tariff to 13 c/kWh for at least 12 years<br>• Speed-bonus (2 c/kWh) for projects operational by the end of 2015<br>• Incentive to self-market (reduction to 3.5 c/kWh after 12 years)<br>• Extension of grid connection obligation for TSO for OWPs with start of construction before the end of 2015<br><br>BNetzA publishes position paper |
| **2009-2011** | Financial crisis 2008 complicates finance of large projects<br>EU “unbundling” regulations in 2009 to separate vertically integrated energy companies<br>German government introduces the KfW-Offshore-Program total of €5 billion liquidity for financing OWPs up to 50% of necessary borrowing |

| | |
|---|---|
| **2011/ 2012** | <u>Grid connection debate</u><br>November 2011: Tennet suspended transmission expansion because of financial, material and personnel shortages ("Brandbrief")<br>January 2012: Philipp Rösler initiates the "AG Beschleunigung," a convent of experts from the industry and government, moderated by the Offshore Wind Energy Foundation |

Sources: Falk and Wagner (2012), Offshore-windenergie.net (2015)

Because spatial planning was not fully centralized and key questions were still unresolved, offshore wind energy development stagnated at the end of 2011. Other than in Germany, wind park developers in the UK had to build the grid connection on their own. A government official recalls: "Our wind parks would be further offshore (than in the UK) (…) Since the North Sea is environmentally protected and there were a lot of shipping routes, we believed the grid connection had to be centrally planned." (Interview, 013115)

But there were two key problems with the position paper by the BNetzA: the criterion of secured finance, which led to an investment bottleneck, and the optimistic calculation of 30 months for the TSO to provide the grid connection, which led to unrealistic time schedules for the wind park developers. In a report, KPMG (2010) foresaw that the investment bottleneck would lead to a supply bottleneck because of the high number of connections that would be simultaneously required in 2012 and 2013. "This may result in delays to grid connections even though all deadlines and criteria are met. (…) Both developers and lenders face significant investment risk in this context." (KPMG, 2010)

Faced with high numbers of granted applications for grid connection, Tennet could not deliver on time because they underestimated the technological challenges. As delays occurred, Tennet and the wind park developers were concerned about liability for forgone revenue and cost overruns. In Tennet's letter of urgency in November 2011, they announced suspension of transmission expansion because of financial, material and personnel shortages, until the liability issue could be resolved. A government representative recalls: "(…) the fact that it was unclear who would be responsible for time delays and cost overruns led to a gridlock." (Interview, 013115)

**Table 5: Timeline for offshore wind development, Transformation Period (2012-2014)**

| | |
|---|---|
| **2012** | EEG-Amendment<br>• Optional "bottom out" model by end of 2017 (19 c/kWh for 8 years)<br>• Alternative: feed-in tariff of 15 c/kWh for at least 12 years<br>• 7% degression from January 1, 2019 onwards<br>• Unlimited obligation for grid connection for TSO |
| **2012/ 2013** | Change of the regulatory system ("Systemwechsel")<br>• EnWG warrants onshore and offshore grid development plan (NEP, ONP)<br>• Spatial planning law and marine facility regulation<br>• BNetzA authority over grid connection regulation<br>• BSH authority over maritime spatial planning and approval for OWPs |
| **2013** | EnWG-Amendment about liability ("Offshore-Haftungsumlage," §17F EnWG)<br>• TSO has to compensate 90% of forgone revenue, due to time delays, to the wind park developer, between €17.5 and €110 million per OWP annually<br>• TSO can charge electricity consumer up to an additional 0.25 c/kWh |
| **2014** | EEG-Amendment revises target expansion from 10GW to 6.5GW in 2020 and from 25GW to 15GW in 2030 |
| **2015** | Expansion of offshore wind capacity to 1GW by the end of 2014 |
| **2020** | Target capacity of 6.5GW |
| **2030** | Target capacity of 15GW |

Sources: Falk and Wagner (2012), Offshore-windenergie.net (2015)

In response to the gridlock, the government undertook a reform program that substantially transformed the regulatory and policy framework. On January 12, 2012, Federal Minister of the Economy Philipp Rösler initiated the "AG Beschleunigung," a convention of experts from the industry (producers, suppliers and lobby organizations) and the government (BNetzA, BSH), moderated by the Offshore Wind Energy Foundation (see Table 5).

The initiative led to amendments of the EEG in 2012 and 2014 (EEG, 2012; 2014) and the EnWG in 2013 (EnWG, 2014). The 2013-EnWG amendments clarified the liability-issue: in case of time delays, the TSO is responsible for 90% compensation to the wind park developer for forgone revenue, including an additional electricity surcharge of up to 0.25 c/kWh.[4] The 2014-EEG amendments revised the expansion

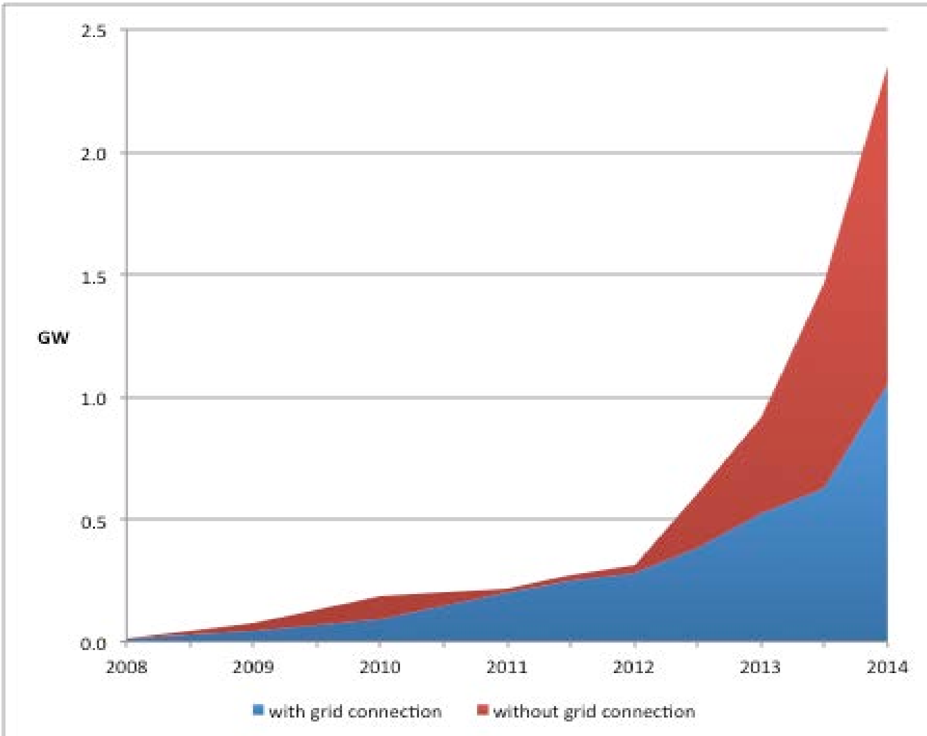
[4] According to a government representative: "We could not grant the wind park developers full compensation, because they would have no incentive for alternative or intermittent grid connectors; but of course, they had to be adequately compensated."

targets from 10GW in 2020 to 6.5GW and from 25GW to 15GW in 2030. Further, the government assigned authority for spatial planning to the BNetzA and the BSH: the four German TSOs (Tennet, Amprion, 50hertz, TransnetBW) are required to report an annual offshore grid development plan ("Offshore-Netzentwicklungsplan") to the BNetzA. Developers are required to apply to the BSH for OWPs to be approved by 2020, followed by an auction system. A government representative recalled: "we need(ed) to balance between (…) wind energy development and the grid expansion, as well as environmental protection." (Interview 013115)

*Actual Capacity Development*

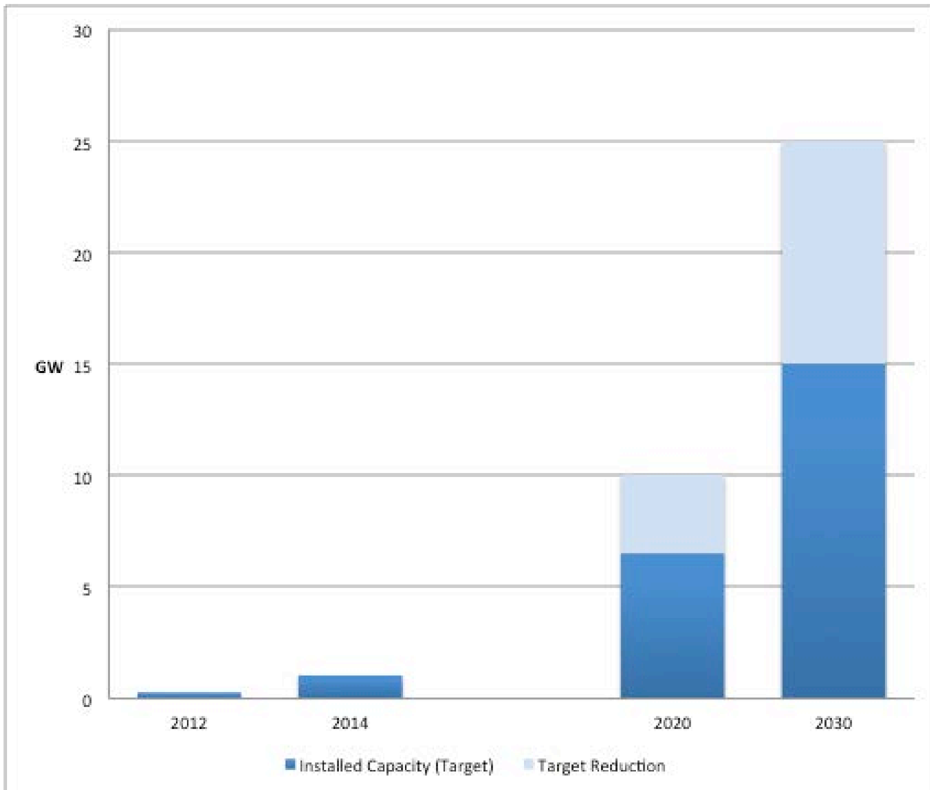
Before the transformation period, expansion in offshore wind capacity was sluggish. By the end of 2012, the wind park developers had only installed a capacity of 280MW (see Graphic 2), significantly below expectations. According to a former engineer, „politicians expected more than the technology could deliver, too much and too early." (Interview, 011415) In the subsequent two years, however, installed capacity increased by almost four times to 1.1GW, with an additional capacity of those awaiting grid connection of 1.3GW and 920MW for those under construction (DWG, 2015). Graphic 3 depicts the expansion from 2011-2015 including the 2020 target of 6.5GW. In a press release, the Offshore Wind Foundation (OWF, 2015) noted that they expected an additional 2GW installed capacity in 2015. If continued, the expansion of offshore wind power capacity is likely to meet the 2020 target. According to Hermann Albers, president of the German Wind Energy Association BWE, "despite all the past challenges, we have achieved a stable growth of offshore wind capacity. The offshore technology (…) is on the edge of a decisive breakthrough." (OWF, 2015)

**Graphic 2: Actual offshore wind capacity development in Germany**




Source: DWG (2015)

**Graphic 3: Offshore wind capacity with grid connection in Germany: 2020 and 2030 targets**




Source: DWG (2015)

## Industrial Development

The previous section looked at the policy context in the wake of the EU unbundling decision and Germany's *Energiewende*. The government decided to regulate the grid connection, which led to a interface issues between wind park developer and TSO. The following section examines how this affected the development of the offshore wind industry in Germany, more specifically the wind park developers, the TSOs and the supplier industry.

*Wind Park Developers*

The wind park developers are responsible for the execution of the project and face the risk factors supply chain, policy uncertainty, governance model and project finance. Because offshore wind projects have long time horizons, they require long-term planning, policy coherence and market certainty

(Interview, 011315.2). A project entails project development, preparation and construction, operating phase (plus possible extension) and decommissioning.[5]

*Supply Chain Logistics*

Supply chain logistics entail all parts of the value creation, from project development, laying foundations, installing and connecting wind turbines to the grid, logistics and operation and maintenance (O&M). In 2008, installation vessels were scarce and maritime infrastructure insufficient (Interview, 011415). OWPs turned out to be a more risky construction environment than previously assumed, because they involved work at sea, at great height and heavy lifting (Skiba and Reimers, 2012). Supply chain logistics can be an enabling factor for an industry and an issue of public policy because sometimes it involves large public infrastructure, e.g. the national grid. In Germany, however, grid connection was legally guaranteed and was, therefore, not a part of the wind park developers' responsibility. According to industry sources, supply chain logistics led to bottlenecks between 2008 and 2012 and slowed industry development, but companies quickly adjusted and found solutions (Interview, 011315.2. Interview, 011415).

[5] Subject of this study is only the cost overrun for the period of construction.

*Policy Uncertainty*

The policy framework is the defining factor for the development of the German offshore wind industry. For one, it determines investment decisions: without a planned market development, ensured by the FITs, a strategy and targets, the industry could not profitably develop. Second, regulatory standards, such as safety and spatial planning, were crucial. German maritime safety standards are stricter than international norms. As a result, a consultant estimated that the material costs in Germany are about 10% higher than those in Belgium, for example (Interview, 011415). In addition, environmental protection standards in Germany are strict and the German "Wattenmeer" is an UNESCO-protected natural habitat; therefore, the turbines had to be built further offshore than in other countries, increasing risk and cost. Third, Germany's infrastructure policy was key to the framework for offshore wind energy. The government obliged Tennet TSO GmbH to provide a guaranteed grid connection. This became a risk for wind park developers, as it led to an investment bottleneck and "forgone revenue" of power generation, which they were later compensated for.

*Governance Model*

The governance model, defined in project contracts, is a key factor for legal risk allocation. The industry used two models: a turnkey contract and a multi-contract model. Between the contracts, there are interface risks, which can lead to delays and cost overruns, e.g. the cable installation contractor cannot lay the intra-array cables if the foundations are not installed (Interview, 011215). If there is a time delay or higher costs, it has to be borne by the responsible party. In the turnkey model, an EPC (engineering, procurement, construction) contractor is responsible for delivering the OWP to the developer. The contractor is in charge of subcontracts, usually between 5 and 20, e.g. for turbine manufacturing or installation (Interview, 011215). In the turnkey model, the wind park developer does not risk increased costs, but pays the contractor a risk premium. This model was used in the first phase of offshore wind energy development in the UK. Because it could not avoid time delays and cost overruns, the developers shifted towards multi-contracting. In this model, the owner is responsible for the interface risks. Without a premium, the total cost is lower, but the owner is not insured against cost overruns (Interview, 011215).

*Project Finance*

Project finance determines the financial risk allocation. Since offshore wind is a capital-intensive industry, and a standard 300-400MW wind park costs, on average, €1.5 billion (Sobotta, 2012), it is usually financed by big utility firms or banks. The project finance usually entails a "contingency budget" for cost overruns (see Böttcher, 2012), which is between 10% and 15%.[6] The contingency budget allows the consortium to adjust cost control and risk allocation. When cost overruns became higher than expected, the investors increased their contingency budgets. An industry source commented: "Nobody knew what would work and now we know that the answer depends on the type of investor, the configuration of the wind farm, and the experience of contractors." (Interview, 011215)

*Transmission System Operators*

Tennet, a Dutch state-owned TSO, faced technological challenges in providing the grid connection, including supply chain and project finance problems, resulting in time delays for OWP connections between 6 and 32 months.[7] After the EU decision to "unbundle" power generation and transmission, Tennet bought the North German grid network from E.ON in 2010, when 23 OWPs were already approved. With the 2006 Infrastructure Planning Acceleration Act (IPAA) and regulatory clarifications, Tennet was obliged to provide the grid connection for the OWPs in the North Sea. The BNetzA-position paper in 2009 determined the expected time period to provide the grid connection to be 30 months as a reference for wind park developers to enable planning. After time delays occurred, Tennet suspended construction in November 2011 because of financial, material, and personnel shortages, until regulatory issues could be resolved. A period of legal disputes followed in which liability in the case of time delays and potentially increasing electricity surcharges for consumers were debated (Wirtschaftswoche, 2012). Currently, the industry plans 50 months for grid connection (Interview, 011315).

**Graphic 4: Grid connection clusters in the German North Sea, map**

[6] This "contingency budget" is different from the cost overruns examined in this study, because those cost overruns are not unplanned. The cost overrun begins as soon as the contingency budget is exhausted.

Source: Modern Power Systems (2015)

**Table 6: Grid connection clusters in the North Sea, key data**

| Project Name | Planned Installation | Wind Park Connections | Capacity (in MW) |
|---|---|---|---|
| Alpha Ventus | 2010 | Alpha Ventus | 60 |
| BorWin 1 | 2010 | BARD Offshore 1 | 400 |
| BorWin 2 | 2015 | Global Tech I<br>Veja Mate | 800 |
| BorWin 3 | 2019 | OWP Albatros | 900 |
| BorWin 4 | 2019 | Deutsche Bucht | 900 |
| DolWin 1 | 2014 | Trianel Windpark Borkum<br>MEG Offshore I | 800 |
| DolWin 2 | 2015 | Nordsee One<br>Gode Wind I<br>Gode Wind II | 900 |
| DolWin 3 | 2017 | Borkum Riffgrund I<br>Borkum Riffgrund II | 900 |
| HelWin 1 | 2014 | Nordsee Ost<br>Meerwind Süd / Ost | 576 |
| HelWin 2 | 2015 | Amrumbank West | 690 |
| Nordergründe | 2016 | Nordergründe | 111 |
| Borkum-Riffgat | 2014 | Riffgat | 108 |
| SylWin 1 | 2014 | Dan Tysk<br>Butendiek<br>Sandbank | 864 |
| Total | | | **8.009** |

Source: Offshorewindenergie.net (2015).

Public voices criticized Tennet for increasing the cost of the *Energiewende* for consumers. Robert Busch, CEO of the federation of new energy suppliers (Verband Neuer Energieanbieter), said: "The planned regulation is a non-transparent contract between offshore wind park operators and transmission system operators to the burden of the consumers. They have to pay, but have no opportunity for budget control of the compensation." (Die Welt, 2012) Tennet was certainly in a difficult situation as they faced a technology and investment bottleneck. Graphic 4 and Table 6 depict the grid connection clusters and the individual projects that Tennet was responsible for.[8]

*Technological Challenges*

Laying underwater transmitter cables far from shore, accurate risk assessment and construction of the converter platforms offshore were the key technological challenges for the TSOs Tennet and 50hertz. More than 100 kilometers distance to shore, in more than 40 meters water depth, an unknown supplier market and the previously untested direct current (DC) transmission technology were crucial factors. "The technology was firstly used in the North Sea and is still in development," a Tennet representative said. "This was new territory for all actors involved, not only us. There was no previous experience we could utilize." (Interview, 012815) As a result, Tennet faced the risk of using infant technology in development, construction and maintenance that can increase costs.

In 2012, Tennet faced problems laying the underwater cables for the alternating current (AC) connected OWP Borkum-Riffgat. Tennet found potentially dangerous wartime material waste at the seabed. CEO Lex Hartmann said they had to pay €57 million for the removal of 30 tons of material within 18 months and €43 million in compensation to Riffgat for forgone revenue (Tennet, 2013). The incident was likely due to an inaccurate risk assessment and a lack of information sharing between Riffgat and Tennet. In August 2013, Tennet connected BARD I, a 400MW-OWP, with BorWin I, in the agreed time period of 30 months. But for reasons that are unclear, BARD I stopped feeding electricity into the grid in November 2013. Certainly, the technology development for grid connection has not reached the maturity stage and further challenges can be expected.

*Supply Chain Bottlenecks*

Supply chain problems entailed delays in components of cables and problems with the construction of converter platforms. Production bottlenecks of transmitter cables are due to low levels of previous demand. Because potential suppliers, e.g. the French company Nexans, Italian Pyrsmian and Swiss-Swedish ABB produced above demand, they were in a period of downsizing before the European offshore wind expansion took off. Wirtschaftswoche (2012) quoted an E.ON manager saying, "the cable market is narrow and monopoly-like." Due to the sudden increase in demand, the cable producers have started expanding their production. For example, ABB invested €325 million in new facilities to double production capacity by 2015. Due to the demand shock, Tennet faced a supply chain bottleneck that led to time delays. Tennet CEO, Lex Hartmann, said delivery times for cables are at 50 months (Wirtschaftswoche, 2012).

Converter stations built by Siemens were the most significant reason for the supply chain bottleneck. Because they underestimated technological challenges, delays in manufacturing and preparing the converters had cost Siemens roughly €900 million in two years (WSJ, 2014). Hans Bünting, CEO of RWE Innogy, said: “I can understand them because they are also in the grip of the supply chain, but we haven’t got a firm date. And I think it is because their supplier also doesn’t have a firm date, so it’s a bottleneck.” (Toptarifnews, 2013)

*Project Finance*

Tennet faced a huge financial challenge. Falk and Wagner (2012) questioned the economic potency of one TSO to meet the requirements of the necessary extension of transmission capacity in Germany. In 2011, Tennet had annual revenue of €1.5 billion and a net profit of €200 million, while the estimated necessary investment in the Netherlands and Germany was around €20 billion for the next ten years. According to a government representative, “We expected the TSOs to anticipate the challenge. But external finance was a problem for them and the technology was completely new." (Interview 013115)

The TSOs needed secure investment in wind park development. But there is a mismatch between grid connection capacity and financed wind park capacity in the North Sea, a Tennet representative said: they had an obligation to construct 7.1GW connection capacity, but only 3.8GW wind park capacity had sufficient finance (Tennet, 2014). “With the EEG amendments, the government took key steps to reduce investment uncertainty. The next year will show if this is sufficient to close the gap between grid connection capacity and electricity generation capacity.” (Interview, 012815)

*Supplier Companies*

Supplier companies face technological and economic challenges related to the wind park developers and the TSOs. To make offshore wind a competitive source of power generation, wind park developers depend on learning curve effects in the supplier industry to drive down costs, e.g. in turbine manufacturing. TSOs contract some parts of the construction of the grid connection out to suppliers, e.g. the construction of the converter platforms to Siemens.

Turbine manufacturing is a capital-intensive process that requires long-term market security (Interview, 011215). OWTs have the highest share of total investment, 35% for offshore compared to 70% for onshore wind (Skiba and Reimers, 2012).[9] To reduce costs, the turbine manufacturers need to achieve a higher scale and build larger turbines. Contrary to the market for cables and transmission, the turbine manufacturing market is more competitive among potential suppliers such as Siemens, Areva, Senvion (former REpower) and Vestas. To have market security, the manufacturers need a long-term commitment by the national governments to support the industry. An industry source said: “The suppliers need to scale up and invest. But they need to know if there will be a sufficient market in the future. With lower targets, they invest less, which tames cost reductions.” (Interview, 011215)

One of the biggest technological and economic challenges is the construction of offshore converter platforms. Converter platforms are wired to the OWTs and transform the generated electricity into direct current (DC), transport it via subsea transmission cables to a station onshore where it is re-transformed into alternating current (AC) and fed into the national grid. Siemens-constructed platforms led to significant problems for the time schedule of the grid connection. Tennet contracted Siemens to deliver four out of eight offshore converter stations in the North Sea. But anchoring foundations for converter stations more than 40m beneath the surface, shipping, installation and starting up grid components became more expensive than expected (WSJ, 2014). Platforms have a unique design and there was no previous experience in technology, regulation and standards (Die Zeit, 2012). In 2014, Siemens said delays in manufacturing and preparing the converters have cost them roughly €900 million since 2012 (WSJ, 2014). Without a converter station, the TSO could not connect the OWTs to the grid. RWE Innogy CEO Hans Bünting said that Siemens was the “weak link” in supplying the connection of their OWP Nordsee Ost. “They (Tennet) have informed us that they are late, and they always blame it on their converter station supplier, Siemens.” (Rechargenews, 2012)

## Case Studies

The above analysis shows that there was an interface problem between wind park developer and TSO, which significantly impacted the supply chain of OWPs in Germany (see Graphic 5). The context was the German policy framework for offshore wind in reaction to the EU’s “unbundling” decision. The interface problem resulted in regulatory uncertainty for an infant industry, which already faced huge technological challenges, supply chain bottlenecks and insufficient finance. Results were time delays caused by grid

[9] Costs of operation, maintenance, logistics and installation are much higher for offshore than for onshore, which drives the relative share of OWT costs down.

connection problems and cost overruns in the construction of OWPs. In the next section, four case studies illuminate the impact of these factors on the development of OWPs in more detail (see Graphic 6). The analysis shows that explanatory factors for time and cost overruns varied among the cases.

**Graphic 5: Illustration of the governance setup**

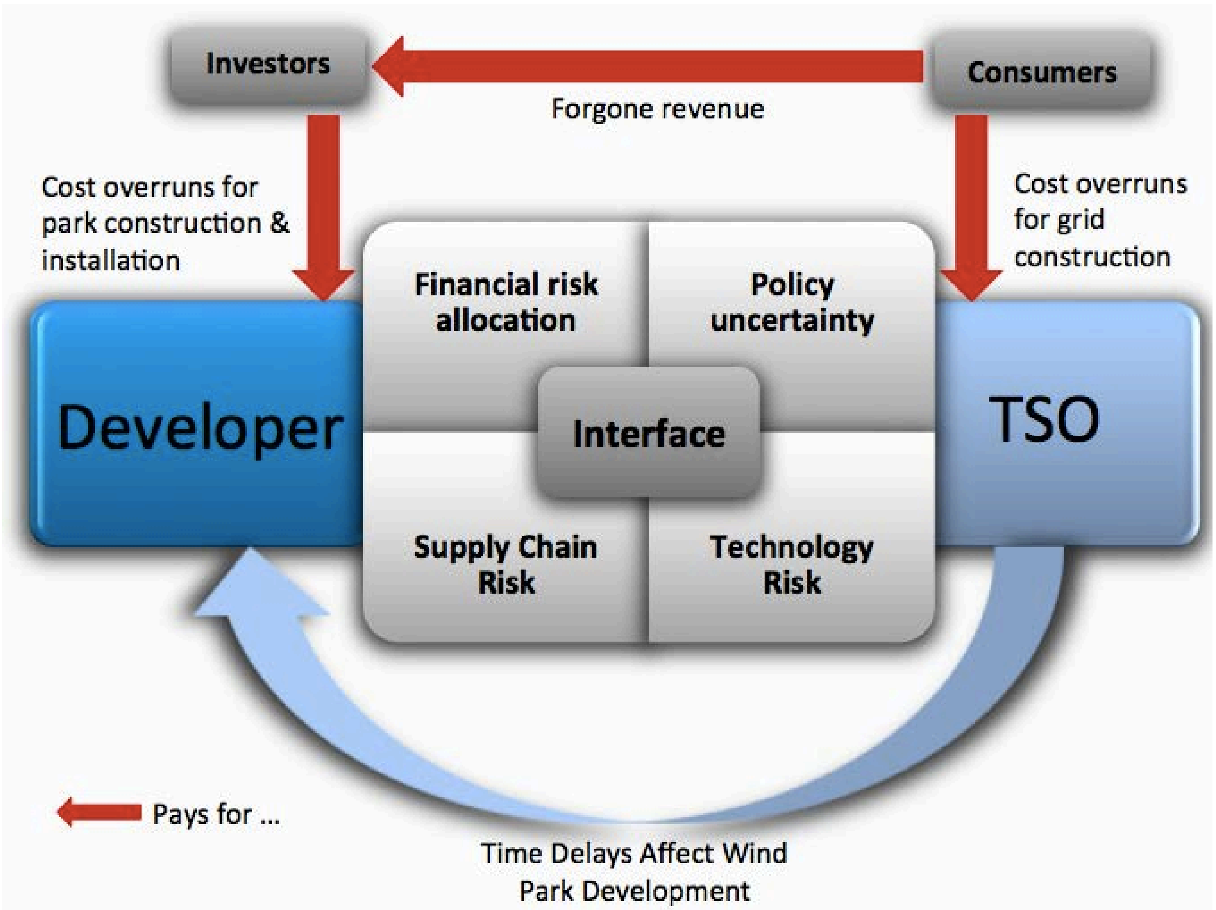


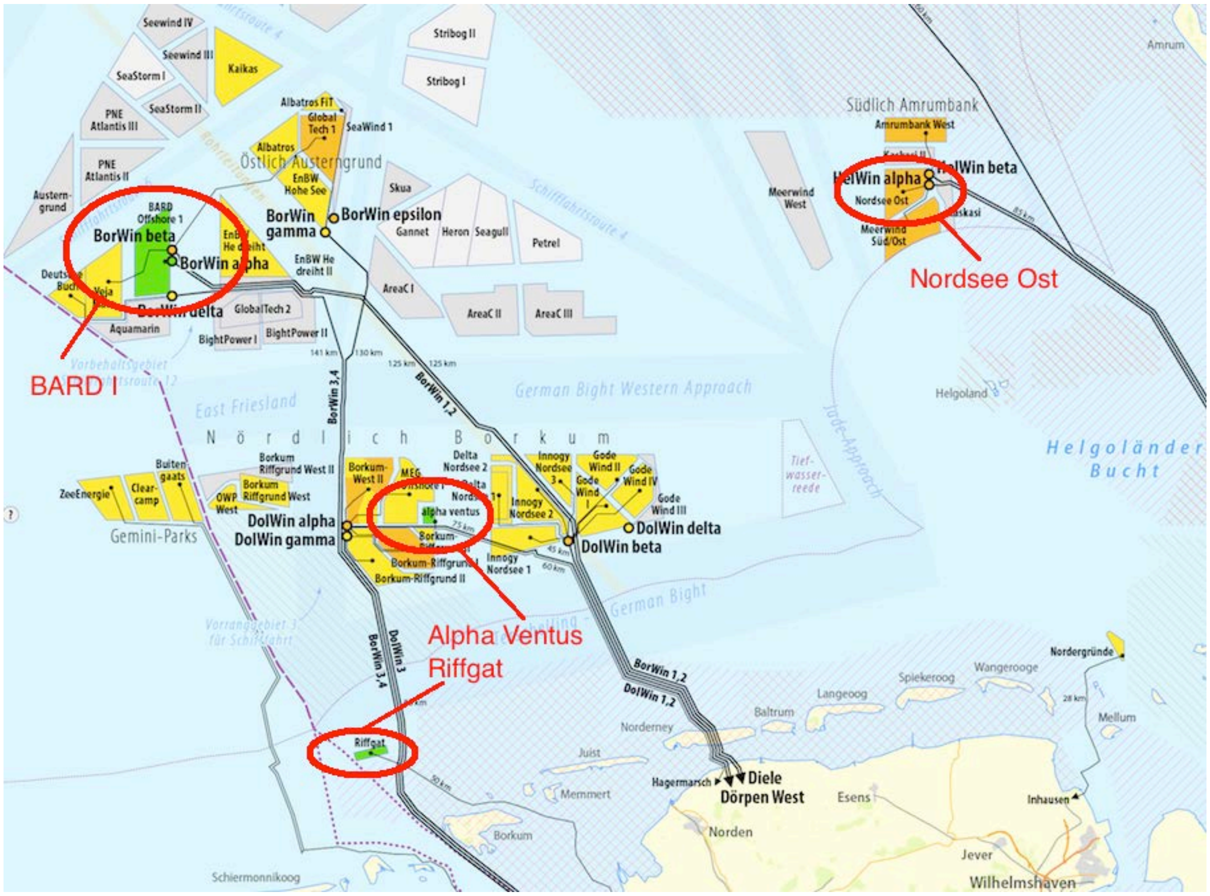
**Table 7: Key factors in four selected case studies**

| | Alpha Ventus | BARD I | Nordsee Ost | Borkum-Riffgat |
|---|---|---|---|---|
| **Developer** | E.ON, EWE, Vattenfall (DOTI) | BARD Engineering GmbH | RWE Innogy | EWE Erneuerbare Energien GmbH, ENOVA |
| **TSO/Grid cluster** | Tennet/None | Tennet/BorWin 1 | Tennet/HelWin 1 | Tennet/None |
| **Capacity** | 60 | 400 | 295 | 108 |
| **Number of turbines (turbine type)** | 12 (6 x REpower 5M, 6 x AREVA M5000–116) | 80 (Bard 5.0) | 48 (REpower Systems 6.0) | 30 (Siemens SWT-3.6-120) |
| **Distance to shore** | 56km | 112km | 51km | 42km |
| **Water depth range** | 33-45m | 40m | 22-25m | 18-23m |
| **Start of construction** | 08/2007 | 06/2009 | 07/2012 | 09/2012 |
| **Planned start of operation** | 2009 | 2011 | 2013 | 2013 |
| **Actual start of operation** | 04/2010 | ? | 12/2014 | 04/2014 |
| **Time delay (in months)** | 12 | >24 | 18 | 6 |
| **Planned cost (in million €)** | 190 | 1500 | 1000 | 480 |
| **Actual Cost (in million €)** | 250 | 2900 | 1130 | 480 (+100) |
| **Cost overrun (in %)** | 32 | 93 | 13 | 0 |

| Name | Key factors |
|---|---|
| **Alpha Ventus** | • Pioneer risk of technology (unknown factors such as wind strength, capacity and transmission)<br>• Challenging installation logistics and maintenance far off the coast<br>• Project management within a consortium of three firms faced coordination problems and unclear responsibilities |
| **BARD 1** | • Isolation from industry development: in-house operation of turbine manufacturing, steel construction, logistics and installation instead of contracting out<br>• Overconfident planners underestimated technological and financial challenges<br>• Firm declared insolvency and a subsidiary of a big bank took over; not operational to date because of transmission problems |
| **Nordsee Ost** | • Supply chain and logistics bottlenecks, especially due to insufficient maritime infrastructure<br>• Strongly delayed grid connection due to challenges of construction of converter platform and transmission<br>• Regulatory uncertainty due to the liability question led to a dispute between RWE Innogy and Tennet |
| **Borkum Riffgat** | • TSO had to pay €100 million for removal of underwater wartime material and compensation for forgone revenue |

| | |
|---|---|
| | • Inaccurate risk assessment before construction of grid connection |

**Graphic 6: Four selected case studies in the German North Sea**




Source: WAB (2013)

*The Pioneer: Alpha Ventus*

As the first German OWP, Alpha Ventus was a pioneer project with a mixed outcome. After several delays of the project before construction start, engineers started first cable installations in August 2007. In September 2008, Alpha Ventus (2008) announced that bad weather conditions would delay construction until spring 2009. Construction ended in November 2009, and the park officially opened in April 2010. Costs increased from planned €190 million to €250 million, 32% above planned cost (MMO, 2010). But it produced 15% more electricity than expected (Alpha Ventus, 2012).

Alpha Ventus launched the start of the offshore wind industry in Germany. In 1999, a small company from Leer planned to build a pilot-OWP 45km north of the island of Borkum. In November 2001, the BSH permitted the park with the condition that construction had to start before April 2004. It did not happen.

In September 2005, the Offshore Wind Foundation (OWF) was newly found due to an initiative by the BMU. OWF intended to build Alpha Ventus as planned and connect it to the grid by 2007 (OWF, 2010). DOTI, a consortium of E.ON, Vattenfall and EWE, founded in June 2006, intended to lay the cable connection between the 12 OWTs and the onshore grid. Supported by a €30 million grant from the BMU, Alpha Ventus was intended to cost €190 million at construction start in 2008 and finish early 2009, accompanied by the research organization, RAVE, to study weather conditions, technology and determinants of electricity generation. An industry source said: "A process of learning and ramping up is not only very normal but also very important to improve processes and organization." (Interview, 011215)

DOTI turned out to be "the most complicated structure one could imagine for the construction of the first offshore wind park in Germany." (OWF, 2010) With different company cultures, frequent changes in project management, organizational structure and internal responsibility, the companies were hesitant to invest (Interview, 011415). The BMU, including Federal Minister Sigmar Gabriel, had to repeatedly intervene to save the project (OWF, 2010). Alpha Ventus reported time delays due to "extreme challenges to installation logistics, construction, project management and the maintenance far off coast." (Alpha Ventus, 2012) Additionally, environmental factors of salty air, strong wind and waves were "massively increasing investment and maintenance costs compared with close-to-coast offshore locations or onshore wind parks." (Alpha Ventus, 2012) In April 2010, Alpha Ventus was finished at a total cost of €250 million and fed electricity into the grid.

Nevertheless, industry and government reacted positively to the finalization of Alpha Ventus. While the developers originally expected 3,900 full load hours per year, Alpha Ventus had 4.450 full load hours, generating 267 GW/h in 2011—15% more than expected. An engineer who was involved said: "It was pioneering work and the project was uniquely challenging. A lot of problems occurred and it became more expensive than intended. But technologically, Alpha Ventus was very successful (…) which created a lot of optimism." (Interview, 011415)

*Large and complex: BARD I*

BARD I is an extreme case compared to the others. In June 2009, the BARD Engineering GmbH started construction of one of the largest OWPs in Europe with 400MW capacity. In March 2010, the first turbines fed electricity into the grid and the park was expected to become fully operational by mid-2011. It was repeatedly delayed and finished in August 2013. Only three months later, BARD I had to be plugged off because of technological problems. It is not fully operational to date. It was originally intended to cost €1.5 billion and was estimated to cost €2.9 billion in January 2012 (UniCredit, 2012).

In 2003, the Russian-German engineer and entrepreneur, Arngold Bekker, had begun planning an offshore wind venture in Germany. A former Gazprom-official and multi-millionaire, Bekker formed the BARD Engineering GmbH (the initials are **B**ekker-**A**rngold-**R**ussland-**D**eutschland) and planned to finance the construction of BARD I with €100 million of his private fortune (Die Zeit, 2009). The company held its own subsidiaries for nearly all parts of the supply chain, including turbine manufacturing, logistics, steel and installation. UniCredit was the main financier, with a 70% share in 2009 and the EU subsidized the project with €53 million (Energie Chronik, 2012). Developing their own turbine, the Bard 5.0, the engineers started construction in June 2009, 112km off Borkum in the North Sea, planning to finish by mid-2011. A consultant said: „It was a mistake to manufacture the turbines by themselves. I could say back in 2006 that this would not work. BARD believed they could take it on all by themselves.“ (Interview, 011415)

The construction period was a disaster. A diver who worked on a trafo platform drowned in June 2010 (Die Welt, 2010). Another worker died in January 2012, when a docking platform he climbed accidentally slid (BARD, 2012). Tennet provided the grid connection BorWin1 without time delays (Energie Chronik, 2012). BARD did not comment on reasons for installation time delays that occurred continuously. But likely, the combination of technological challenges and the ambitious undertaking of manufacturing turbines in-house, resulted in investors gradually loosing confidence as setbacks and incidents mounted.

In August 2013, BARD finished construction, but had to declare insolvency. Ocean Breeze, a subsidiary of UniCredit, took over. In November 2014, unexpected electricity transmission disturbances occurred. Ocean Breeze assigned a task force with Tennet and ABB to investigate (IWR, 2014). To this day, the task force did not find a cause. BARD I had damaging repercussions for the offshore wind industry in Germany and worldwide. Critics in Germany problematized the cost of the *Energiewende* (Die Welt, 2014). The Economist (2013) called the project an “expensive disaster.”

*Facing typical problems: Nordsee Ost*

Nordsee Ost, substantially larger than Alpha Ventus, faced problems often observed in the development of offshore wind energy in Germany: time delays caused by the grid connection, regulatory uncertainty, supply chain bottlenecks and technological challenges. Originally intended to finish in late 2013 and cost €1 billion, engineers started construction of Nordsee Ost in July 2012. It finished in December 2014 and had a 13% cost overrun (€130 million).

RWE, a utility firm, faced public criticism for not investing in renewable energy in Germany. In February 2008, RWE founded a subsidiary, RWE Innogy, to bundle and expand their renewable energy portfolio, which included biomass, solar and onshore wind (RWE, 2014). RWE had offshore wind industry experience in the UK, but closer to shore and with smaller turbines. RWE decided to invest in Germany and take over the Dutch company Essent, including their project pipeline: Nordsee Ost, already in the pre-construction phase, and Nordsee One, Two and Three, with a planned total capacity of 1.3GW (Interview, 011415). Between 2008 and 2012, Nordsee Ost faced construction delays because maritime infrastructure was insufficient, with too few installation vessels to sustain difficult work at sea. In 2012, RWE bought two installation vessels and founded a subsidiary for installation logistics to support their projects (Interview, 011315.2; Interview, 011415).

After the logistics bottleneck was solved, the grid connection debate began in Germany. RWE Innogy CEO Hans Bünting criticized regulatory uncertainty caused by the government. He said: "There is a lack of standardization and centralized planning, and this leads to lack of certainty in the supply chain — and that all leads to the mess we see today." (Rechargenews, 2012). Because Tennet was late in finishing the converter station HelWin1, Nordsee Ost faced a time delay of 18 months. RWE Innogy threatened legal action against Tennet, claiming that delays cost them up to €12 million per month (Toptarifnews, 2013). An industry source commented: "The transmitter cables, converter platforms and other components were not available on a tech supermarket, but uniquely challenging as the technology was young and huge investments were necessary." (Interview, 011315)

After the liability-issue was solved with the 2013-EnWG amendments, the debate ebbed. In December 2014, all OWTs of Nordsee Ost were installed and the company expects commercial operation in spring

2015 (RWE, 2014). RWE managers said they have learned from their experience with Nordsee Ost and will improve if political certainty remains (Die Welt, 2014).

*Staying on budget: Borkum-Riffgat*

Riffgat has no reported construction cost overruns, but faced time delays caused by the grid connection. After repeated delays of construction start due to technological and political problems, engineers started construction of the 30 OWTs in September 2012 for a planned €480 million investment. Because Tennet had to remove wartime material from the seabed to lay underwater transmitter cables, the grid connection cost €57 million more than planned. Riffgat avoided sources of cost overruns that other projects did not, such as the turnkey contract for the subsea station, but the increased cost of €100 million in total was controversial in the media because consumers had to pay (FAZ, 2014). Riffgat was technologically easier than other cases studied, because it was the closest to shore and in the shallowest water, potentially an enabling factor for more successful planning.

EWE and ENOVA, two regional companies, planned Riffgat in 2000 and founded the consortium Offshore Riffgat GmbH & Co KG. In 2010, the project developers obtained permission and approval for grid connection for Riffgat, planning to start construction in 2011 and finish by the end of 2012 (Riffgat, 2015). Riffgat is 42km off the island Borkum in the North Sea and within the 12-mile nautical zone of Lower Saxony, which launched an “Action Program Offshore Wind Energy” at the time. Other than for Nordsee One, Tennet was not legally responsible for the converter platform. Instead, it was built by Strukton-Hollandia under a turnkey contract (Strukton, 2015). Riffgat is in a sea area, whose demarcation line between the Netherlands and Germany had not been finally concluded. Speculatively, this dispute led to delays in construction start (FAZ, 2014). In 2012, investigations by Tennet for laying the subsea transmitter cables found more wartime material under water than previously known. Their CEO, Lex Hartmann, said they paid €57 million for the removal of 30 tons of material within 18 months, as well as €43 million compensation to Riffgat for forgone revenue (Tennet, 2014).

Tennet was accused of insufficient risk assessment and preliminary investigation. A risk consultant said: "Going about it that way is dangerous, and highly expensive." (WPO, 2014) But possibly, Riffgat did not communicate their knowledge with Tennet effectively (EEM, 2014). In August 2013, Riffgat was operational, but had to wait for grid connection until February 2014. Reportedly, electricity production was higher than expected (IWR, 2014).

## Discussion

*Two Types of Cost Overruns*

Because of the interface problem between wind park developers and TSOs, this study distinguishes between two types of cost overruns. First, the wind park developer has a cost and time schedule regarding the EPC tasks of the project. For any problems in the value chain that cause cost and time overruns, there is a responsible party as defined by the contracts. Secondly, the TSO has a cost and time schedule for providing the grid connection. For time delays, the TSO has to compensate 90% of the forgone revenue of electricity production to the wind park developer, in turn compensated for by higher electricity prices for consumers. Table 8 depicts the scale of cost overruns resulting from this distinction.

**Table 8: Scale of cost overruns until the end of 2014**

| | Compensation for loss | Total additional costs (in million €) | Average cost overrun per OWP (in %) |
|---|---|---|---|
| **EPC** | Private (Investors) | 1890 | 20 |
| **Grid (forgone revenue)** | Public (Consumers) | 1047 | 15 |
| **Grid (construction)** | Public (Consumers) | *unknown* | *unknown* |
| | **Total** | 2937+ | 35+ |

### Construction of the Offshore Wind Park

The average cost overrun for OWP construction and installation is 20% for finished projects. From previous analysis, a number of explanatory factors could be deducted. According to this model, the key factors for project delivery are supply chain logistics, governance model and project finance. It depends on the individuals firm’s performance whether it can learn from previous failures to avoid cost overruns and reduce cost. Firms can mitigate cost overruns by selecting proper risk allocation models (contracts, insurance, contingency budgets etc.). An example of good performance, according to industry sources

(Interview 011315. Interview 011415), is DONG Energy, because they have achieved the scale to build integrated supply chains which helped them solve logistical and financial problems that other wind park developers faced (however, their German OWPs are not in the sample, because they are still under construction).

### Surcharge Addition due to Time Delays

The average surcharge addition per finished OWP is about €132 million, which equals a 15% average uptake per OWP.[10] The electricity surcharge addition is the money compensated by the TSO to the wind park developer, paid by an electricity surcharge according to the §17F EnWG ("Offshore Haftungsumlage"). An information platform of the German TSOs reported the cost to be €295 million in 2013, €762 million in 2014 and €491 million in 2015 (Netztransparenz 2013, 2014a, 2014b). A TSO representative said the total of €1.5 billion will not significantly increase over the next few years, because five grid connections are already operational and the subsequent projects will not be delayed as much. Surcharge additions can be seen as the specific additional cost of public planning of the development of offshore wind energy in Germany.

## Conclusion

This study looked at the scale, patterns and causes of time delays and cost overruns in offshore wind power expansion in Germany. Germany had very ambitious targets to make offshore wind a market-competitive source of power generation and an essential pillar of its *Energiewende*. But this development faced governance problems due to interface complexity between wind park developers and TSOs. The industry faced technological, financial, supply chain related and political challenges in construction of the wind park at sea, resulting in an average cost overrun of 20% per OWP. But time delays in the grid connection were an additional factor that led to additional costs of forgone revenue compensation to the wind park developers of more than €1 billion by the end of 2014. These results

[10] This number does not take into account: cost overruns due to construction costs of converter platforms and grid connections (e.g. Borkum-Riffgat cost €57 million more) and the potential for wind park developers to use an intermediate grid connection to mitigate against losses.

show that a “semi-private” megaproject such as offshore wind expansion has specific governance problems with the risk of time delays and cost overruns, for both private and public shareholders and stakeholders.

Based on the results of the study across sectors, another key finding is that offshore wind parks are better planable than other large-scale projects (see Anzinger and Kostka, 2015). Nuclear reactors had an average cost overrun of 187% for six cases in the Hertie School Infrastructure Database. In previous studies, Sovacool et al. (2014) also found a 117% cost overrun for 180 nuclear reactors. They also found a 8% cost overrun for 35 wind parks, both onshore and offshore. Their explanation for this low cost overrun is better standardization and quicker construction lead times (average 12.6 months), compared, for example, to nuclear power (average about 90 months). The findings of this study confirms that those factors are the most likely explanation for the lower cost overruns in offshore wind parks compared to other projects. But because of unanticipated challenges in offshore wind compared to experiences in onshore wind, there have, nevertheless, been higher costs involved. The key challenge, this study finds, is the interface of offshore wind parks with grid connection and expansion.

## Recommendations

Cost overruns and time delays for construction and installation of offshore wind parks are a manageable issue, as the industry is maturing and learning from experience. But the impact of cost overruns and time delays in grid connection and expansion is underexplored. Based on the results of this study, the author recommends:

- Strengthening coordination between TSOs, wind park developer and supplier industries
- Coordinating with governments of North Sea countries to enable long-term planning, share best practices and develop transnational scenarios for offshore wind and grid expansion and interconnection (e.g. North Seas Countries Offshore Grid Initiative)
- Developing a policy framework for the expansion of offshore wind after 2020 that enables investment security, competitiveness and regulatory coherence

- To identify potential problems and find better solutions, the Federal Ministry for Energy and Economy should order a study on the impact of time delays and cost overruns in grid contruction on total costs of offshore wind expansion
- To avoid further ad-hoc measures, an independent auditor should assess potential sources of time delays and cost overruns, develop accurate estimates for financial contigency budgets as well as risk insurance models.

Offshore wind power is likely to assume an important role in Germany's energy mix. It will remain a key challenge for the industry, government and the public to find the right solutions to make the *Energiewend*e succeed.

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