DAUPHINE UNIVERSITÉ PARIS | 129 ENERGIE FINANCE CARBONE (EFC)

Research thesis presentation

Obstacles and challenges in developing an offshore wind supergrid in the North Sea

TXEM ANALYTICS

The issues behind the NSCOGI

Research Thesis as part of the Master's Program in Energy-Finance-Carbon at Université Paris-Dauphine

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I. Definition of a super-grid

Professor Christian Von Hirschhausen from the University of Dresden defines them as follows:

"It is commonly accepted that a 'super-grid' refers to a transcontinental power network that interconnects existing grids. (...) Super-grids are characterized by:

- Flexibility in balancing supply and demand;
- High generation capacity;
- Significant geographical distances."

II. Presentation of the NSCOGI

The North Seas Countries' Offshore Grid Initiative (NSCOGI):

- **A regional cooperation project** for the development of an offshore wind super-grid in the North Sea;
- **10 participating countries:** Germany, Belgium, Denmark, France, Ireland, Luxembourg, Netherlands, United Kingdom, Sweden, and Norway;
- **Declaration of Intent signed on December 7, 2009.**

Project objectives:

- Identify national policies impacting the development of offshore wind power;
- Facilitate and coordinate the development of the super-grid;
- Establish the necessary regulatory framework for the project.

II. Presentation of the NSCOGI

Governance of the NSCOGI:

- Rotating presidency among member countries, led by their respective energy ministries;
- Oversight committee composed of ACER and ENTSO-E;
- Support provided by the Benelux Union, the Electricity Regional Initiative (ERI), and the Trans-European Networks for Electricity (TEN-E).

Three working groups:

- Grid configuration;
- Regulatory issues;
- Management of planning and permitting aspects of the project.

Recent Reaffirmation of NSCOGI's ambitions:

- Renewal of the declaration of intent in 2016;
- New tasks outlined for the 2016–2019 period.

II. Presentation of the NSCOGI

Benefits of unifying offshore wind in the North Sea via a super-grid:

- Improved management of intermittency;
- Reduction in CAPEX (e.g., technology standardization, shared infrastructure).

Strategic advantages of the North Sea:

- Largely composed of continental shelf, resulting in shallow waters (average depth: 94 meters);
- Consistent and strong wind conditions;
- Estimated potential of 100,000 MW of wind capacity and 300 TWh by 2050, according to TenneT and Energinet.

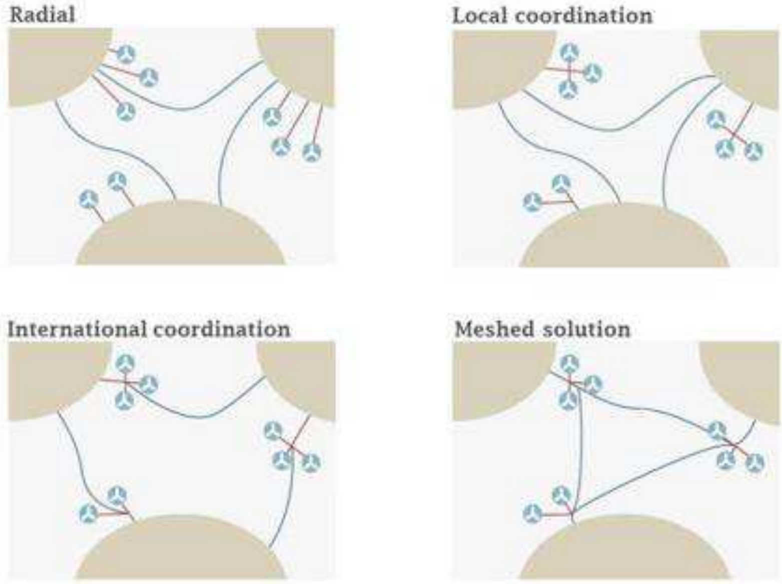
Pre-NSCOGI initiative:

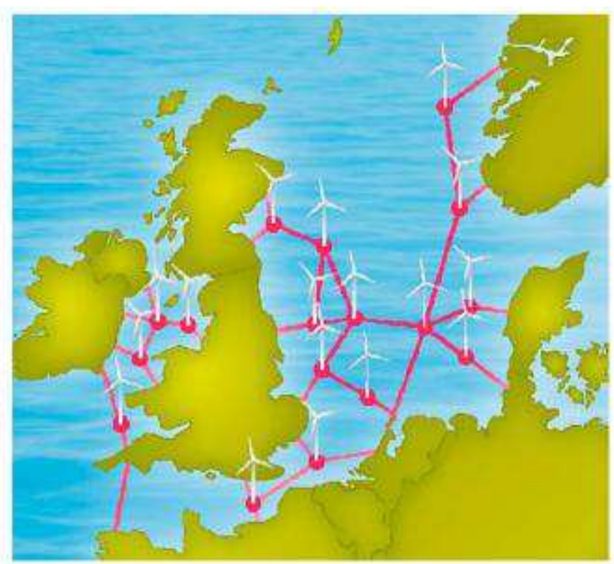
- In 2006, the Irish wind developer Airtricity and the Swiss company ABB expressed interest in an offshore wind super-grid extending from Spain to the North Sea, aiming to smooth production through an HV DC network (High Voltage Direct Current).

II. Presentation of the NSCOGI

NSCOGI's proposal for a meshed grid, rather than a radial one:

- Shared investment in infrastructure;
- Increased resilience to technical failures;
- Easier power distribution thanks to a higher integration rate of intermittent generation;
- Strong requirement for cooperation to enable the deployment of the super-grid.



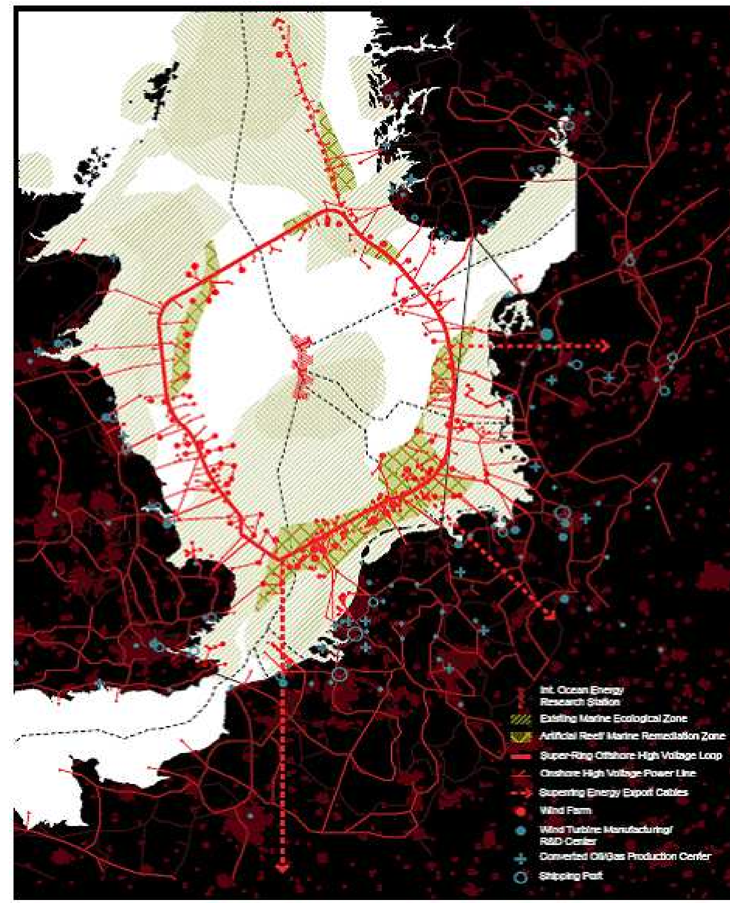


Source: NSCOGI, 2012 and Friends of the Supergrid

II. Presentation of the NSCOGI

Alternative proposals to NSCOGI's meshed grid, the "Ring" concept by the Offshore Grid Association:

- Interconnection in the form of a giant ring;
- The association estimates that 13,400 TWh could be harnessed in the North Sea (based on figures from Energinet and TenneT);
- However, low resilience to technical failures;
- Strong constraints on the geographic location of the wind farms.



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III. Energy independence issues for the European Union

A very serious situation of energy dependency for the European Union:

- In 2014, 53% of the gas and oil consumed by the EU was imported, representing €400 billion in losses, compared to the €34 billion trade surplus of the EU-28 in 2016;
- Failure of the EU's LNG deployment policy in the 2000s, due to high prices and limited cooperation among Member States for gas transit;
- Long-term gas supply contracts imposed by the EU on Russia following the Russia–Ukraine crisis, made possible by Europe's storage capacity and domestic production, but European gas production is now in sharp decline.

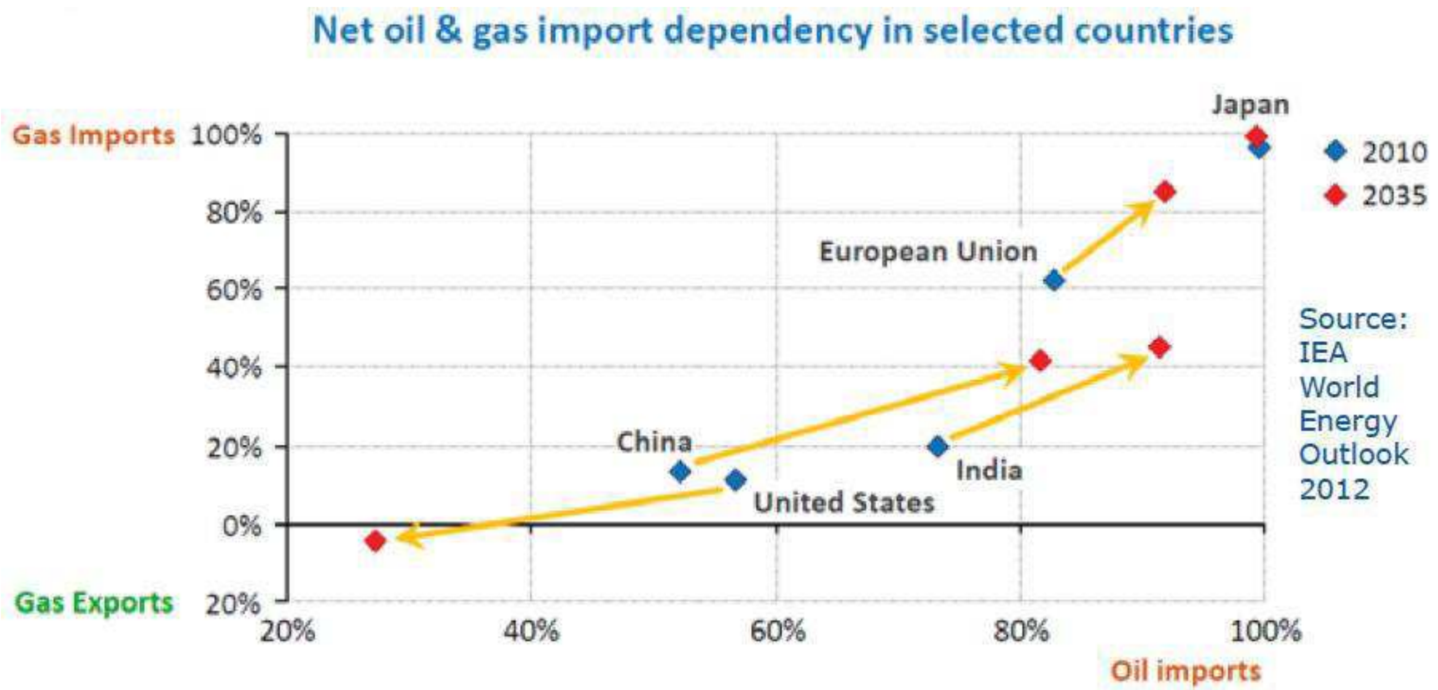
III. Energy independence issues for the European Union

Europe's main fossil fuel reserves are being depleted:

- Decline in UK oil & gas production, as the UK became a net gas importer in 2004; its dependence on fossil fuel imports rose from 2% in 1990 to 43% in 2015;
- Groningen gas field in the Netherlands will be 80% depleted by 2017;
- 131 nuclear power plants were over 29 years old as of 2014;
- Technically recoverable shale gas reserves in Poland were estimated at over 5,300 billion m^3 in 2011, but revised down to a maximum of 768 billion m^3 in more recent estimates.

III. Energy independence issues for the European Union

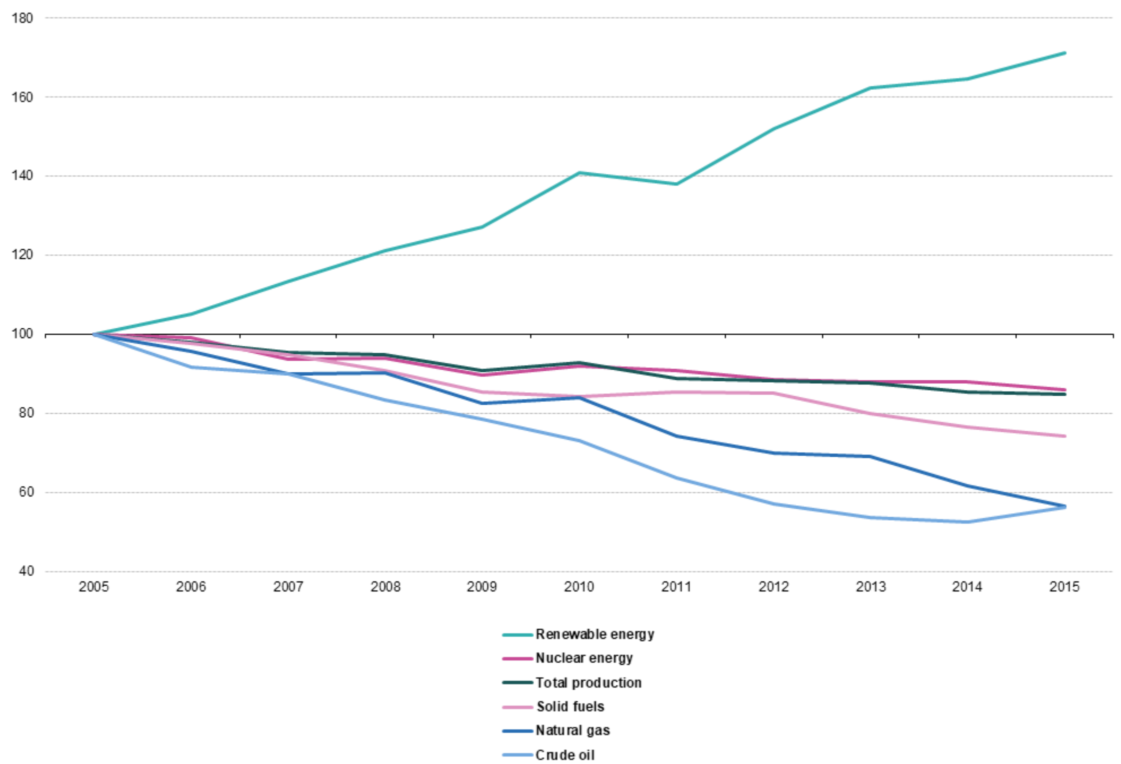
Sharp increase in European energy dependency projected by the IEA, as dependency on natural gas is expected to rise by more than 20 percentage points by 2035:



Source : International Energy Agency, *World Energy Outlook*, 2012.

III. Energy independence issues for the European Union

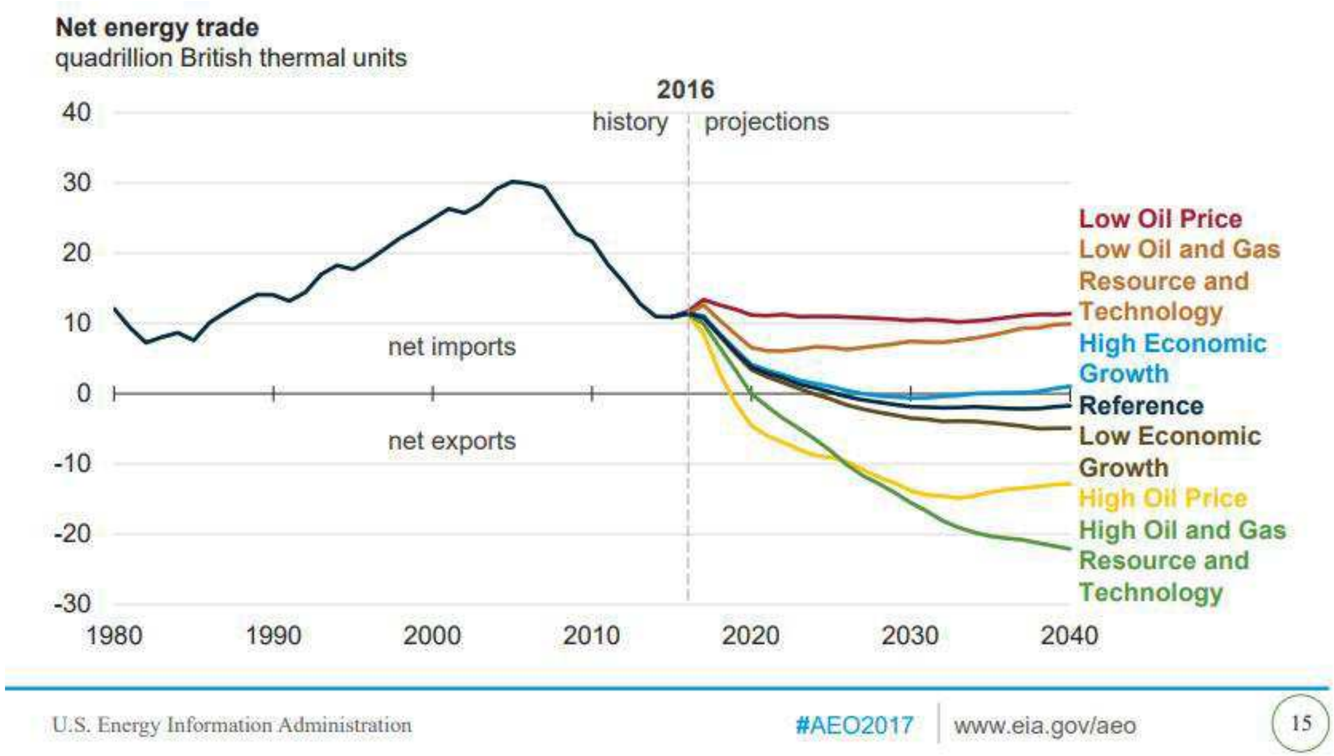
Development of primary energy production, with 2005 as the reference year, for the EU28:



Source: Eurostat (online data code: nrg_100a)

III. Energy independence issues for the European Union

Opposite situation in the United States, raising concerns over a significant loss of economic competitiveness for the EU:



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IV. The offshore wind context in Europe

Late 2016, sharp and unexpected drop in offshore wind CAPEX:

- Three offshore wind farms proposed by Dong (now Ørsted) and EnBW without subsidies (grid parity) off the coast of Germany;
- Production costs close to €35/MWh (excluding grid connection), compared to €200–220/MWh for the French offshore wind feed-in tariffs at the time.

March 2017, TenneT and Energinet announced the signing of a Memorandum of Understanding for the development of the North Sea Wind Power Hub — involving the construction of infrastructure on Dogger Bank in the North Sea and the development of Power Link Islands (6 km² artificial islands acting as network hubs).

July 2017, commissioning of one of the world's first floating offshore wind farms — the 30 MW Hywind Scotland pilot project by Statoil (now Equinor), off the Scottish coast — showcasing strong potential to reduce CAPEX and expand the range of viable locations.

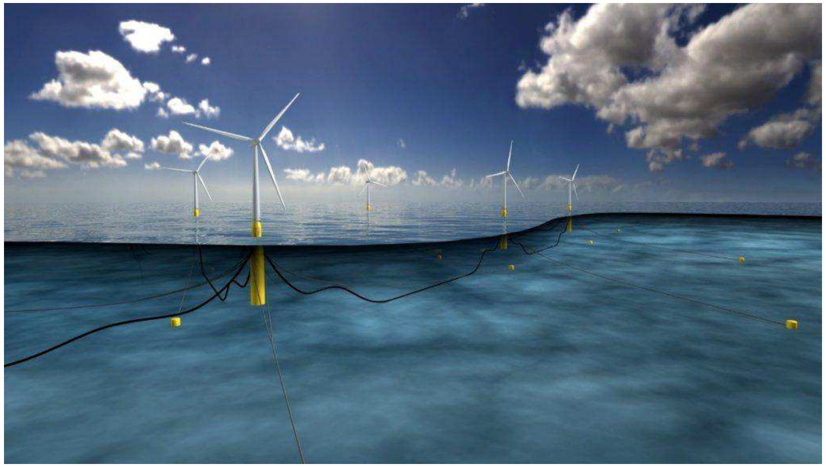
As of July 2017, 12 GW of installed offshore wind capacity in Europe, including:

- 5 GW in the United Kingdom
- 4 GW in Germany
- 1.3 GW in Denmark

IV. The offshore wind context in Europe

TenneT and Energinet's Power Link Island, serving as a grid hub.

Hywind Scotland by Statoil, 30 MW of floating offshore wind capacity.



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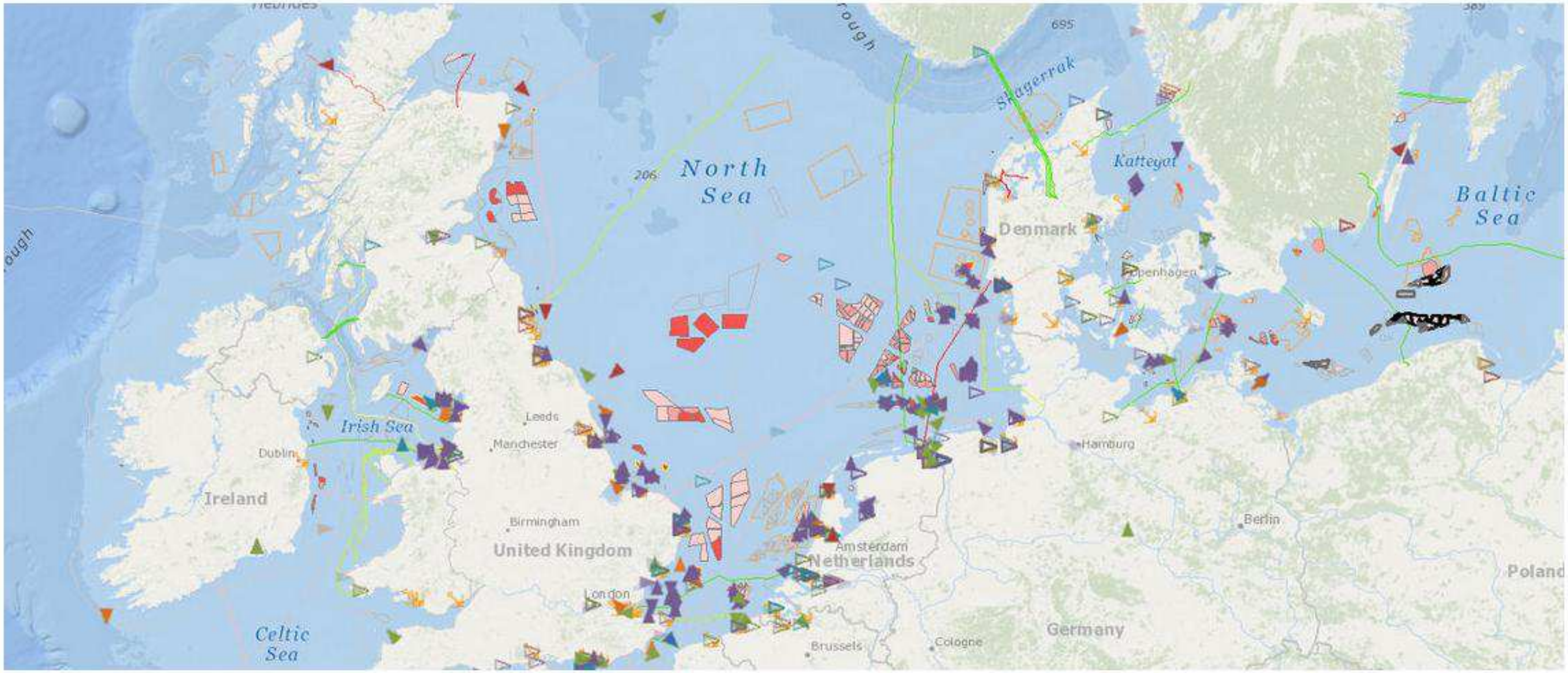
IV. The offshore wind context in Europe

Current and announced offshore wind farms:



V. Obstacles to the implementation of the super-grid

Technological constraints

The construction of offshore wind farms does not pose a major technological constraint for the development of a supergrid in the North Sea:

- The sector benefits from Oil & Gas technology, enabling the construction of structures similar to offshore oil platforms;
- Similarly, submarine power cables have been the subject of extensive R&D due to decades of operational experience with this technology.

The major constraint is the limiting penetration rate of offshore wind power the European grid can accommodate, and several possible pathways are being considered to increase this rate:

- Storage of surplus production via Norwegian hydropower, with an estimated 20 GW of available installed capacity, according to Norwegian authorities;
- Integration of production via HVDC (High Voltage Direct Current) – for lines over 1,000 km, HVDC has lower losses than HVAC (High Voltage Alternating Current), as there is no capacitive loss;
- Optimization of grid design;
- Alternative study of the European North Sea Energy Alliance, supported by the European Commission, with power-to-gas storage using offshore oil wells in the North Sea.

V. Obstacles to the implementation of the super-grid

Technological constraints

The issue of production storage is a challenge at the intersection of technological and regulatory aspects:

- The need to increase the acceptable penetration limit rate is linked to the regionalization of grid supervision;
- This requires a complete overhaul of the organization overseeing electricity production and the involvement of transnational managers, but it faces strong opposition from individual States.

V. Obstacles to the implementation of the super-grid

Technological constraints

Evolution of backup power requirements in the short, medium, and long term:

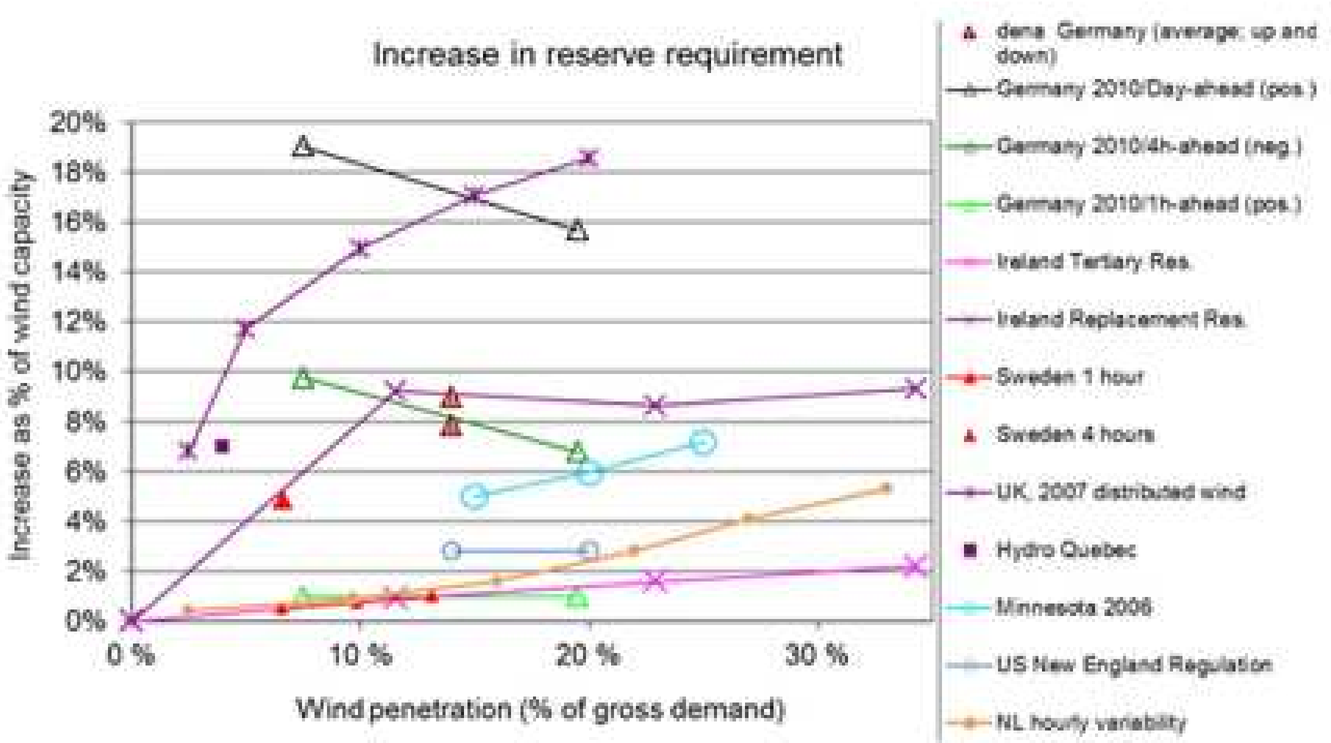


Figure 1. Results for the increase in reserve requirement due to wind power, as relative to wind penetration level.

V. Obstacles to the implementation of the super-grid

Technological constraints

Evolution of adjustment costs across multiple grids:

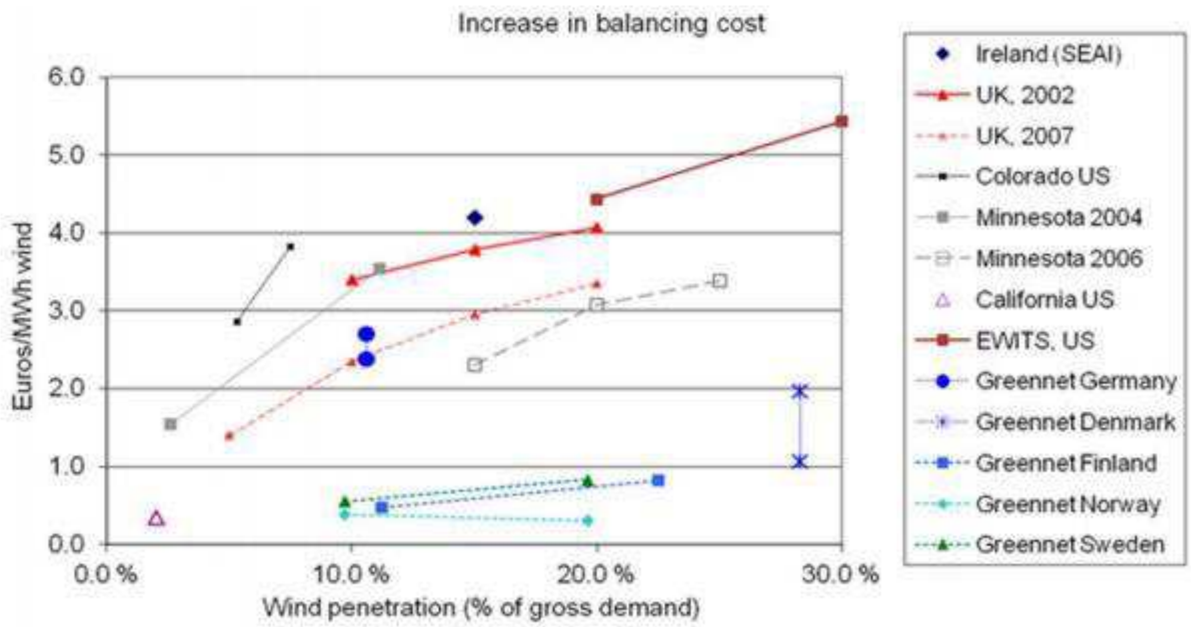


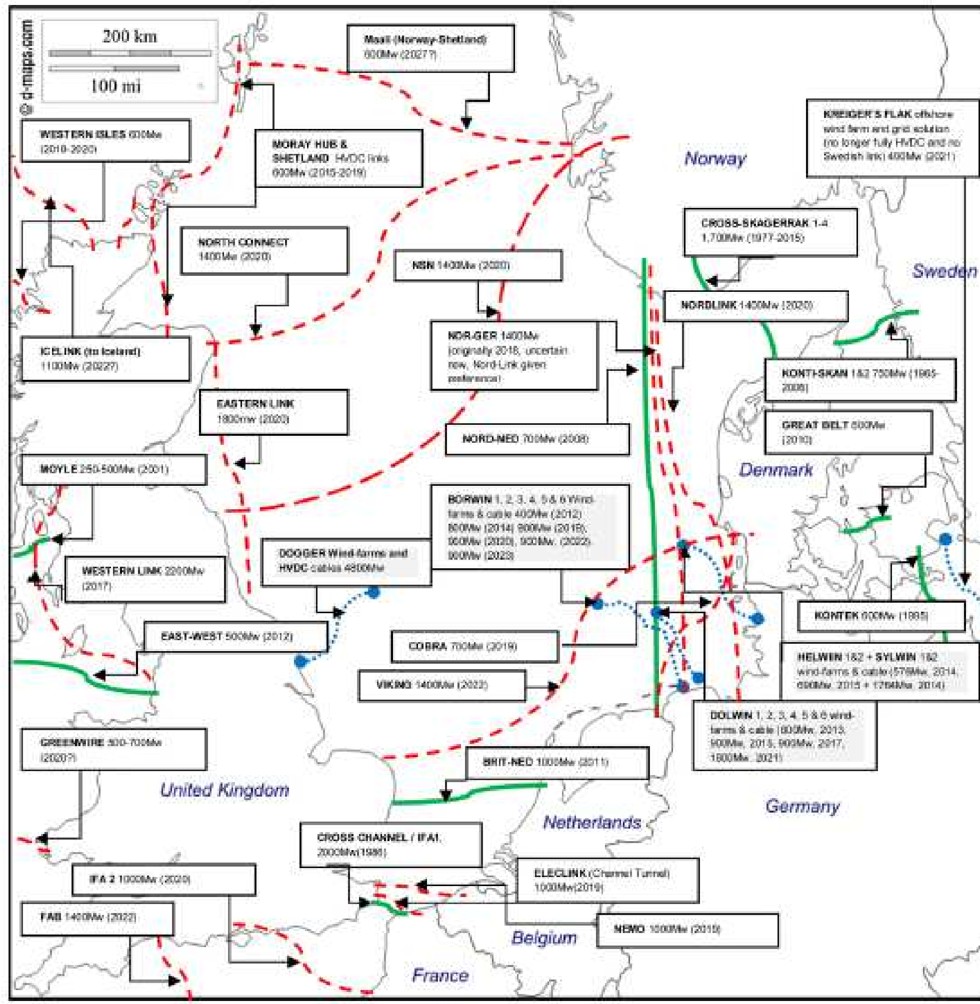
Figure 2. Results from estimates for the increase in balancing and operating costs due to wind power. The currency conversion used here is 1 € = 0.7 £ and 1 € = 1.3 US$.

V. Obstacles to the implementation of the super-grid

Technological constraints

Interconnections made without considering the opportunities of an offshore wind supergrid:

- Several HVDC projects have been developed, but none are sized to accommodate the transmission of wind power;
- A bilateral approach to interconnections has been taken, rather than a multilateral approach, with no regional strategy for grid management.



V. Obstacles to the implementation of the super-grid

Regulatory issues

Inadequate national grid management:

- Following the Barcelona European Council in 2002, Member States were required to achieve an interconnection level equivalent to at least 10% of their installed production capacity; this target was not met by 2013;
- 2006 Blackout: Collapse of part of the European grid due to a technical error in Germany. There was a lack of international coordination between European TSOs in managing the outage, which caused the failure to spread;
- National rather than regional pilot for supply security (e.g., national management of consumption peaks).

Ineffective and disparate economic incentive tools:

- "Missing Money“— markets and capacity mechanisms do not send price signals that align with the long-term risks of power plant projects for grid backup. The IFRI urges States to "react urgently" due to concerns that the continuity of electricity generation may not be ensured;
- Long-term grid management is ensured through diverse economic incentives, all at the national level;
- "Bridges to Nowhere," according to the Florence School of Regulation, for example, no economic incentives in France for interconnections with Spain, despite the need to export renewable energy to the Iberian Peninsula.

V. Obstacles to the implementation of the super-grid

Regulatory issues

Proposal from the Winter Package – November 2016 – to ensure security of supply:

- Acknowledgment of the need for coordination between TSOs and regulators across European countries;
- Proposal of several levels of integration for electricity grid management, including the regional level, to improve security of supply;
- Definition of a "Region" by the European Commission as a group of Member States sharing the same regional coordination center, as established under Article 33 of the proposed "Electricity" regulation;
- Need for coordination between economic incentive mechanisms and markets;

➡ The regional grid management model is particularly well suited to the deployment of a North Sea super-grid.

Implementation of CBCA (Cross-Border Cost Allocation):

- Allocation of the economic benefits of interconnections;
- However, debate continues over the variables used in the proposed calculation methods;

➡ The distribution of interconnection gains is essential for the successful development of the offshore wind super-grid.

V. Obstacles to the implementation of the super-grid

Strong opposition due to economic and geopolitical reasons

Mismatch between National and European economic optima:

- The structure of States, industries, and economies is not well suited for effective cooperation in Europe.

Brexit and the destabilization of the UK's renewable integration process:

- Uncertainty regarding the integration of the UK's energy mix into the broader European mix;
- Delays in negotiations at the level of NSCOGI, ENTSO-E, the EU, and individual Member States for the development of a North Sea super-grid;

➡ Risk of uncoordinated, fragmented development of offshore wind in the region.

V. Obstacles to the implementation of the super-grid

Strong opposition due to economic and geopolitical reasons

Opposition from industry:

- Risks related to electricity prices — potential for a significant drop in electricity prices;
- ➡ Risk to national industries (e.g., potential loss of competitiveness for the French nuclear sector);
- Destabilization of national energy stakeholders;
- ➡ Increased economic competition for former state monopolies.

Governmental opposition:

- The energy sector is a pillar of national economic planning and a key element of a country's diplomatic positioning;
- Loss of sovereignty through the delegation of energy decisions to a regional operator and regulator;
- The French Energy Regulatory Commission (CRE) stated that "The management and regulation of the electricity transmission network is a strategic task, as it is essential for supply security and the safe operation of each country's grid. It would not be easy to relinquish, even partially, such a task from national control."

VI. Appropriate analytical tool for these challenges: the game theory

Development of the North Sea super-grid as a typical case of game theory application:

- Misalignment between individual actors' optima and the group optimum, across all types of stakeholders (e.g., industry players, governments);
- Potential to mathematically model the project's constraints to prioritize them and better understand the mechanisms limiting the super-grid's development;
- Provides a possible negotiation framework for the distribution of economic benefits resulting from achieving the European economic optimum among national actors;
- Serves as a pedagogical tool.

Conclusions

Findings:

- Interconnection projects in the North Sea are being developed without accounting for offshore wind potential;
- Similarly, offshore wind farms are being planned without integration into a super-grid framework;
- Failure of the NSCOGI initiative;
- Strong national opposition to the project;
- The window of opportunity for developing a super-grid is shrinking as offshore wind farms are already emerging independently.

Numerous and significant consequences for Europe:

- Suboptimal use of the North Sea's offshore wind potential;
- Missed opportunity to enhance European energy security;
- Missed opportunity to improve Europe's economic competitiveness;
- Missed opportunity to fight energy poverty—both at the individual and State level;
- Missed opportunity in the fight against climate change.

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