The IEE Project OffshoreGrid: Objectives, Approach and First Results

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Abstract:

An offshore power transmission grid in Northern Europe has become a serious and important topic among the power industry, the power transmission sector, national governments and the European Commission. The *OffshoreGrid* project will provide policy recommendations for the political process towards such a grid in pursuing the efficient integration of renewables, the integration of market regions, security of supply and the competitiveness of the European economy.

OffshoreGrid will develop a scientific view on an offshore grid along with a suited regulatory framework considering technical, economic and policy aspects. The project is targeted towards European policy makers, industry, transmission system operators and regulators. In first instance, the geographical scope is Northern Europe.

The paper covers the general approach and objectives of the project. Furthermore, the first results of the preparatory work packages are presented and discussed.

Introduction:

The ambitious targets and plans for offshore wind power development in the European seas, with in particular the North Sea, has given rise to questions on how to connect the future wind power capacity to and integrate it into the national power systems in an efficient and secure way. In this respect, the issue of an offshore power transmission grid in Northern Europe to (inter)connect the power systems and the offshore wind farms has repeatedly been brought up.

However, several barriers – technical, market, legal, regulatory – hinder its development. Moreover, an objective view on the optimal layout, the associated costs and the necessary requirements to proceed is currently unexisting.

The OffshoreGrid project [1] will provide policy recommendations for the political process towards such a grid in pursuing the efficient integration of renewables, the integration of market regions, security of supply and the competitiveness of the European economy. This paper covers the general approach and objectives of the OffshoreGrid project. Moreover, the first results of the preparatory work packages are described, which include a preliminary discussion and analysis of the model inputs concerning status and future trends of European market integration, and a discussion on the methodology and status of the wind power generation scenarios.

IEE project OffshoreGrid

Objective

OffshoreGrid will develop a scientific view on an offshore grid along with a suited regulatory framework considering technical, economic and policy aspects. The project is targeted towards European policy makers, industry, transmission system operators and regulators. In first instance, the geographical scope is Northern Europe (regions around the Baltic and North Sea, the English Channel and the Irish Sea). In a second phase, the results will be applied to the Mediterranean region in qualitative terms.

The study must serve as background and supporting document for the preparation of further legislative measures. In particular, the outcomes should serve as input for the current work on infrastructure by the European Union as outlined in the Second Strategic Energy Review, namely the Baltic Interconnector Plan, the Blueprint for a North Sea Offshore Grid and the completion of the Mediterranean ring.

The general strategic objectives of the project are:

- Recommendations on topology and capacity choices
- Guideline for investment decision & project execution
- Trigger a coordinated approach for the Mediterranean ring

As specific objectives, the project aims at providing:

- Insight in interaction of design drivers and techno-economic parameters
- Business figures for investments and return
- A selection of blueprints for an offshore grid
- Representative wind power time series
- Feedback from & acceptance by stakeholders

Project DNA

OffshoreGrid is a techno-economic study from a consortium with 8 European partners in consultancy and applied research (Table 1). The project budget is 1.4 million euros, of which 75% is funded by the Intelligent Energy Europe programme. The project has started in May 2009 and will be finished in October 2011.

Table 1: OffshoreGrid Project Consortium

Participant name	Short name	Country
3E	3E	BE
Deutsche Energieagentur	Dena	DE
ECBREC Institute for Renewable Energy	ECBREC IEO	PL
Senergy Econnect Limited	SEL	UK
SINTEF Energy Research	Sintef	NO
National Technical University of Athens	NTUA	GR
European Wind Energy Association	EWEA	BE
University of Oldenburg	Uni Oldenburg	DE

Methodology

In order to achieve the specific and strategic objectives, the OffshoreGrid project builds on 10 work packages with different types of activities:

- WP1 – Management,
- WP2 to 8 – Techno-economic tasks,
- WP9 and 10 – Communication.

The techno-economic work packages can be subdivided into three project phases:

- Preparation (WP2: 'Regional power markets in Europe' and WP3: 'Offshore power generation scenarios'),
- Techno-economic modelling (WP4: 'Scenario specification and version control of techno-economic work', WP5: 'Offshore grid design optimisation and required investments', and WP6: 'Offshore power market modelling'), and
- Conclusions, transfer and recommendations (WP7: 'Transfer to the Mediterranean region: power markets, wind power development and intercontinental transmission' and WP8: 'Discussion and policy recommendations').

In the preparatory phase, offshore power generation data and scenarios will be developed. The scenarios will consist of time-series of offshore wind power generation with high temporal and spatial resolution. For other marine renewables and power demand from the oil and gas industry estimates are made.

The input from the preparatory phase will be used in two techno-economic modelling tasks focussing on offshore grid infrastructure and on the offshore power market. This modelling will be carried out in two or more stages in an iterative process.

The results will finally be transferred in qualitative terms to the situation in the Mediterranean region. Conclusions and policy recommendations will be drawn for all regions.

Activities up to now

The project has officially started in May 2009. The work on 'WP2: Regional Power Markets in Northern Europe: Inventory and Trends' and 'WP3: Offshore Power Generation Scenarios' is still ongoing. The first deliverables will be finished soon, and include a description of the status and future trends of European market integration and an inventory of possible wind farm locations with installed capacity and expected interconnection schedule for the 2020 and 2030 scenarios.

First results

Northern Europe and the Mediterranean: inventory and trends (WP2)

Work Package 2 will prepare the required input for the modeling work packages. It will deliver:

- Input data for the modelling task in WP4, 5 and 6, regarding the current and anticipated status of market integration (all seven regions to be analysed)
- A selection of fuel and CO2 price scenarios for WP4 and subsequent use for market simulation in WP6 along with a critical review,
- An analysis of offshore grid design drivers based on stakeholder interviews as input for grid scenario definition in WP4 and subsequent use in WP5.

The first preliminary results are the analysis of fuel costs, CO2 price scenario's and installed power plant capacities. Furthermore, the results include an analysis of the influence of market coupling on the load flows. The most important sources used in this work package are summarized in Table 2.

Table 2: Most important sources used for the analysis in WP2

Topic	Most important sources
1. Installed electricity generation (scenarios and Status Quo)	o European studies: ▪ Eurelectric, Eurprog, 2008 ▪ DG Tren, Trends to 2030, update 2007 ▪ IEA, World Energy Outlook, 2008 ▪ Ewi/ Prognos, Energiereport IV, 2006 o Examples of national studies: ▪ (Germany) Federal Government for Economy and Technology (BMWi), Energiestatististiken, 2008 ▪ (Poland) Polish National Energy Policy, 2009; ▪ (Spain) Red Eléctrica de España (REE), el sistema eléctrico español, 2008
2. Fuel Cost Scenarios	o European studies (see point 1 and): ▪ Eurostat, Energy - Yearly Statistics, 2007 ▪ Eurostat, online statistics: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics o Examples of national studies: ▪ (Germany) Bundesanstalt für Geowissenschaften und Rohstoff (BGR), Energierohstoffe 2009
3. CO2 Price Scenarios	o European studies (see point 1and): ▪ Deutsche Bank (DB), Global Markets Research: Carbon Emissions, 2008 ▪ ECX (www.ec.eu), EUA Futures Contract: Historic Data, average of all setting prices, 2009 o Examples of national studies: ▪ (Germany) Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU), Leitstudie, 2008
4. Fact-Sheets	o Dena-Country Reports (based on legal and regulatory documents, newsletter, sector specific journals, internet research) and updates of the regulatory facts

- **Regionally specific: fuel costs**
  In contrast to the existing world market price for oil, fuel costs differ significantly between continents, regions and even neighbouring states. This is for instance due to differences in taxation, delivery costs (e.g. geographical aspects), promotion and regulation systems or the market design. To estimate the development of fuel prices for power stations (coal, oil, gas) different available energy economic scenarios and outlooks have been analysed and evaluated. These energy economic scenarios include the latest DG TREN scenarios calculated with the PRIMES model, the IEA World Energy Outlook, publications from the GreenNet project and scenarios proposed by different institutions (e.g. EWI/ Prognos, Eurelectric), etc. None of the energy outlooks covers all of the 35 countries needed, therefore national energy outlooks must be analysed as well.

  First results:

  - Different scenarios for the crude oil prices are compared in Euro/MWh in Figure 1. The scenarios differ significantly; a well chosen scenario will be of vital importance for the relevance of the study results. The analysed energy outlooks suggest that the different fuel types have the same price throughout Europe.

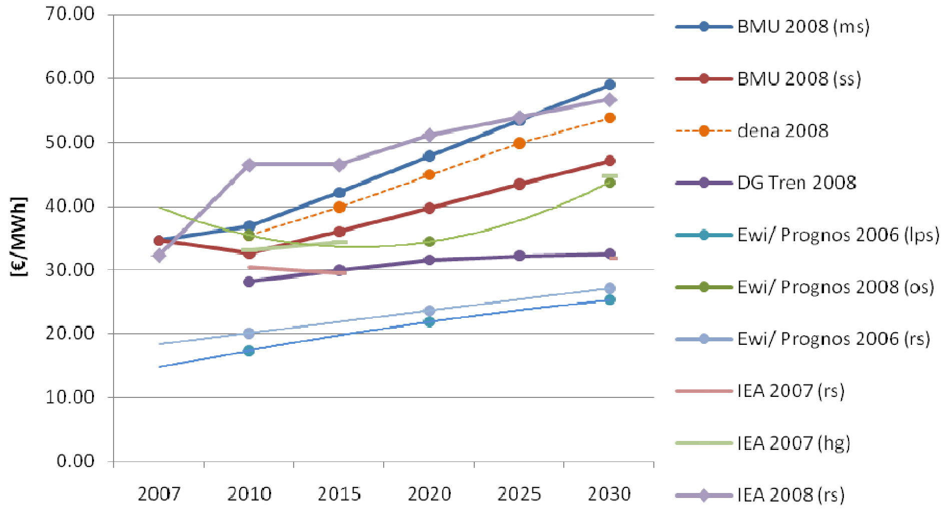

Figure 1: Comparison of different scenarios for border prices of crude oil

  - In reality especially natural gas prices differ significantly in the European countries. This is not based solely on transport costs, but on negotiations with natural gas suppliers. Future gas scenarios for each country with existing price differences will therefore be analysed. Gas powered electricity production units often serve as the ‘marginal’ units in the merit-order curve, with the result that the gas price often sets the electricity price. The gas price scenario is therefore very important for electricity market modelling.

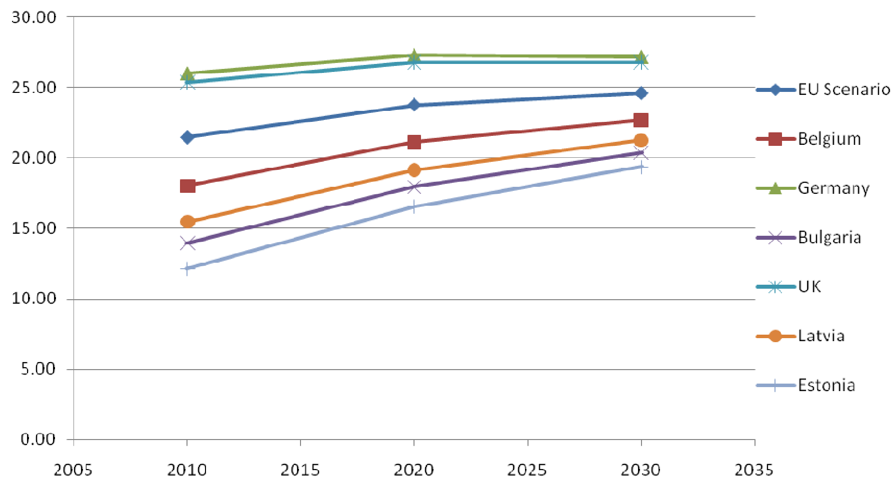

Figure 2: Comparison of different scenarios for natural gas prices

- A world market price for lignite does not exist. Thus, whenever lignite is part of the power plant fleet in a country, we will consider a European price. However, if the countries have differing price assumptions we will take these into consideration. For instance in Germany the lignite power plant owners and lignite mines are often part of the same utility. For the modeling (operation planning of the power plants) we consider for lignite not the full prices but the variable costs of the mining. Therefore, the price for lignite in Germany is only one-third of the price in other European countries.

- **CO2 price scenarios**

  In 2005 CO2 certificates were introduced in Europe. The CO2 price is a new cost element for the use of fossil fuels. To estimate the price development of CO2 certificates available studies have been examined. These are e.g. the “Leitstudie” from the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, the study on carbon emissions from the “Deutsche Bank”, the DG TREN scenario and trading prices for EU emission allowance (EUA) futures.

  First results:

  - The EUA future prices are lower than the forecasts of all analysed studies. This means basically that the studies project a higher degree of shortage than the market does.
  - The CO2 price scenario of the “Deutsche Bank” is much higher than the prices of other studies. “Deutsche Bank” developed a price estimation with a backcasting method. “Deutsche Bank” projects that the EU CO2 savings goals will only be reached with this estimated level of prices. This implies that the actual trading prices for EUA futures are not high enough to reach the EU saving goals.

- **Regionally specific: installed power plant capacities**

  One important input factor for the energy model is the installed power plant capacity and its future development (the offshore wind capacities will be analysed in WP3 by IEO ECBREC). Different studies (see studies of fuel costs) show to some extent different development estimations, therefore an evaluation of the different studies has been carried out. The goal is to provide an accurately analysed estimation of future installed power plant capacities.

  First results:

  - Because of the data coverage and the relatively good consistency with national energy capacity forecasts the Eurelectric Eurprog study seems to fit the requirements of the model best.
  - As described for fuel costs none of the studies covers all 35 needed countries, therefore national capacity outlooks must be analysed.
  - In general national forecasts have higher estimations for renewable energy capacities than European studies.

  In a second step the location of the capacities will be identified. Then the capacities will be allocated to the grid nodes in the 35 countries.

- **Regional and national surveys for North and Baltic Sea countries**

  An offshore grid will involve many countries, market-, tariff-, regulation and wind-promotion-systems. The different systems lead to additional challenges for the integration of offshore wind. Solution strategies for these challenges have to be based on the analysis of the regional and national systems for the support of offshore grids in the North and Baltic Sea countries. The national surveys will help to answer questions such as: Who has to pay the promotion for electricity produced in Germany, sold at the Dutch power exchange to a French supplier? Thus policy recommendations for the efficient functioning of electricity markets with offshore power will be provided. Furthermore regulatory changes for transnational interconnections of offshore sites will be recommended.

  First results:

  - Structure of the regional and national-surveys has been decided on.

- First drafts of the first countries are developed.

- **Analysis: How does the question of market coupling influence load flows?**
  Under the precondition of a continuous trade of the allocated interconnector capacity the market design options (implicit or explicit auctions) will not influence load flows. This is caused by the ambition of all market participants to maximise their benefit (minimise their losses). The participant who could gain the highest benefit in a transnational energy trade will be willing to pay the highest price for the use of the interconnector capacity. This leads to an identical allocation of interconnector capacity through implicit and explicit auction.

  In reality the interconnector capacities are not continuously tradable. It has been shown that the interconnector capacity allocation is partly inefficient (e.g. at TradeWind D7.2 [2]). The information on the influence that market coupling has on load flows is relevant for the model design. On account of this it will be analysed how and to which scale market coupling options influence load flows.

  To verify empirically the influence of market coupling on load flows, data of countries before and after market coupling with implicit auctions will be reviewed. Countries to be considered are for example Germany and Denmark or Belgium, Netherlands, Luxemburg, France.

Offshore Power Generation Scenarios (WP3)

The main objective of this work package is to provide input to the modelling work packages WP4-6 on possible installed capacity and power output which needs to be incorporated into the European grids.

- **Wind power scenarios**
  As a first task a realistic scenario of the growth of installed capacity is being prepared, based on plans of offshore wind development and already identified locations. A database of offshore wind farms projects and concepts has been established and the data collection is completed (final verification necessary). For the moment (September 2009) the database covers 373 records, including projects and areas available for offshore wind development from 15 countries (BE, DK, EE, FI, FR, DE, UK, IE, LV, LT, NL, NO, PL, RU, SE. The basic data collected are projects coordinates, capacity, expected year of installation and grid connection point. In addition some other data have been included, if available (wind farm owner/developer, type of turbines, area covered by project, current project status). The total installed capacity of the offshore wind farms in the database is about 185 GW. Around 50 GW of these projects are relatively well defined, and have a potential of being in operation in 2020. The rest of the database records cover project ideas or areas accepted for future development. In this case only basic information is available (location and potential installed capacity). Those projects have a potential of implementation for 2030 and beyond.

  Based on the information collected, scenarios of installed capacity for 2020 and 2030 are being developed, on a project and cluster basis. The moderate scenario of interconnection will be formulated, considering realistic chances of offshore wind market growth.

  The next steps in this progress include:
  - The final verification of the database content (including outcome of Stockholm Offshore Wind Conference & OffshoreGrid first Northern-European Stakeholder Workshop)
  - Completion of the collection of information about grid connection points, taking into account Deliverable 2.4 of the IEE WindSpeed project [3] for the projects in the North Sea.
  - Final agreement on and acceptance of offshore wind development scenario for 2020 and 2030.

- **Wind power generation time series**
  The second task of the third work package is to develop high-resolution time series of wind speed and power which can be used for the modelling tasks in WP4-6. For all single wind farm locations defined in the first task of this work package, synchronous hourly time series of historical wind speed and power are calculated with a high-resolution weather model. The simulated period will comprise four years (2004-2007), with the focus on the year 2007.

  The calculations are performed with the Weather Research and Forecasting Model called WRF [4], which is a meso-scale numerical weather prediction model with the ability to simulate the atmospheric conditions over a wide range of horizontal resolutions from 100 km to 1 km. The input for WRF is provided by the 6-hourly global analysis data (Final Analysis, FNL) from the United States' National Centers for Environmental Prediction (NCEP).

The WRF-simulations dynamically downscale the FNL data from six-hourly resolution on a horizontal grid of 1° by 1° to one-hourly data on a 9x9 km² grid. (In geographical coordinates, 1° corresponds approximately to 50-110 km.)

Different spatial resolution is foreseen for the regions in focus and the remainder of Europe:

- Europe north of the Alps, including offshore regions in focus: 9x9 km²
- Europe south of latitude 48°N: 27x27 km²

The geographical domains used for the WRF simulations are shown in Figure 3.

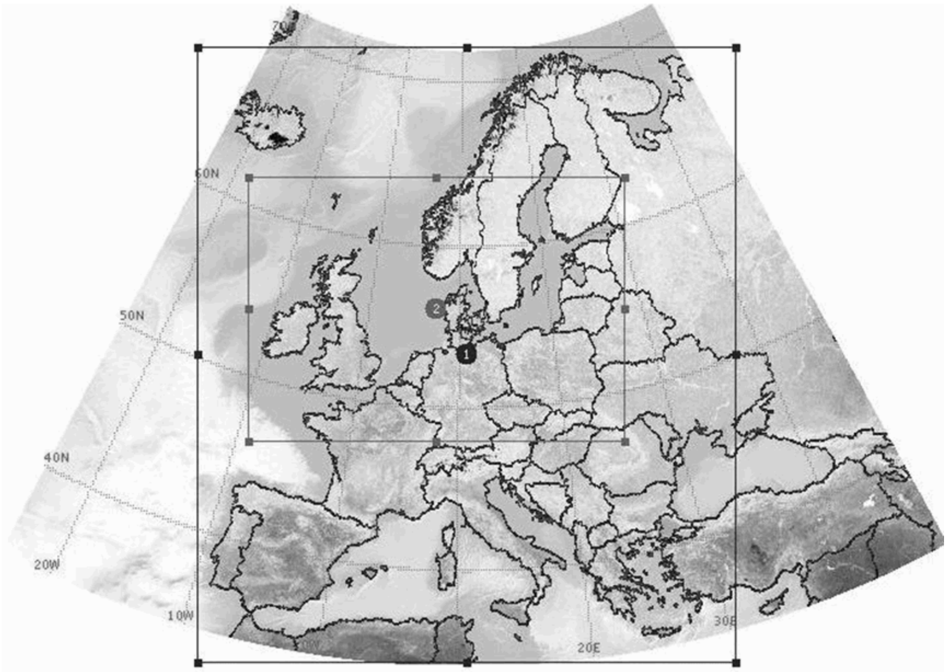

Figure 3: Domains for wind field simulations (1: 27kmx27km, 2: 9kmx9km resolution)

The model output is validated with wind speed measurements at different heights, e.g. from the German offshore platform FINO-1. The wind speed time series can be calculated for all relevant hub heights, e.g. 90m or 100m. Special attention is paid to the vertical wind speed profile and the thermal stratification, which are modelled here with an improved MYJ-Scheme for the Planetary Boundary Layer (PBL).

The next step comprises the conversion of wind speed to wind power. This depends on the wind turbine characteristics represented by the power curve. Standard power curves are given for a single wind turbine. In order to model the output of large wind farms distributed over a region, newest available results in the wind energy community on real-life offshore power curves, array losses due to wake effects, electrical losses and turbine availabilities will be used in this project. Moreover, the applied “effective” power curves have to anticipate possible future improvements in wind turbine efficiency and increased hub heights.

The WRF model runs have been set up and calibrated. The calculation of the time series will be started as soon as the installed wind power capacity scenario is finalised.

Conclusions & next steps

OffshoreGrid is an ambitious research project within the Intelligent Energy Europe programme. It will analyse the requirements for a regulatory framework related to offshore transmission considering technical, economic and policy aspects, and it will help the different stakeholders to come to a common view on the development of offshore electricity grids in Europe. Furthermore, it will serve as a supporting document for further legislative measures on electricity infrastructure on EU level.

The next expected results are the final deliverables of the preparatory work packages, which end at the end of December 2009. These include an assessment of the trends in regional power markets, an analysis of the offshore grid design drivers, an inventory of the possible wind farm locations with installed capacity and expected interconnection schedule for the 2020 and 2030 scenarios, a report on other marine oriented grid development scenarios, and a report on the development en conclusions of time series of wind power output.

The techno-economic modelling work packages start in November 2009. The results from this work are expected in January 2011. The final OffshoreGrid project report is expected at the end of 2011.

Acknowledgement

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