Final report

1.1 Project details

Project title	Deltagelse i IEA Wind Task 26: Cost of Wind Energy - fase 3
Project identification (program abbrev. and file)	Journal number 64015-0564
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	Ea Energianalyse a/s Gammeltorv 8, 6.sal 1457 København K
Project partners	DTU Management Engineering
CVR (central business register)	28 98 58 27
Date for submission	21-12-2018

1.2 Short description of project objective and results

The purpose of the IEA Wind TCP Task 26 project is to enhance international collaboration on understanding of cost and technology trends in wind power. The project uses transparent methodologies and disseminates information in order to enable knowledge sharing within the broader electric sector.

Achieved results include:

- Data analyses
  - Updated data, analysis and understanding of wind energy cost trends, drivers and comparison among countries
- Other research topics
  - Expert elicitation study on future cost of wind energy
  - Analysis of technology trends in repowering projects
  - Analysis of the value of wind energy in power systems and dependence on technology choice
- Dissemination
  - Online data platform for technology trends on land based wind based on project level data
  - Collaborative journal articles summarizing and further analysing trends in cost of wind energy
  - Workshop and experts meetings on methods to value wind energy and to evaluate historical and future technology cost

Formålet med IEA Wind TCP Task 26 er at udarbejde, dele og formidle vide om de teknologiske fremskridt indenfor vindkraftteknologien. Projektet anvender transparente metoder og formidler viden for at frem videndeling om vindkraft i den bredere energisektor.

Opnåede resultater inkluderer:

- Data analyse
  - Opdaterede data, analyser og forståelse af teknologisk udvikling og drivere indenfor vindenergi, samt sammenligning på tværs af lande
- Andre forskningsområder

    - Analyse af ekspertrundspørge om udvikling af omkostninger for vindenergi
    - Teknologiske trends indenfor repowering projekter for landvind
    - Analyse af værdien af vindkraft i elsystemer, og afhængigheden af teknologivalget
    -
- Formidling
    - Web-baseret data-visning om teknologiske trens for landvind
    - Udgivelser i videnskabelige journaler, der sammenfatter og analyserer tendenser for omkostningen ved vindenergi
    - Workshops og ekspertmøder om metoder for at værdiansætte vindenergi og for at evaluere historiske trends og fremtidige teknologiomkostninger

1.3 Executive summary

The purpose of the IEA Wind TCP Task 26project was to enhance international collaboration on understanding of cost and technology trends in wind power. The project used transparent methodologies and disseminates knowledge on wind power to the broader electric sector. Project goals include enhanced international collaboration in the field of cost of wind energy, updated data and analyses on current wind technology and cost trends, analyses on expected cost and value of wind power and dissemination of project insights to the broader electricity sector.

The IEA Wind TCP task 26 participants collected data for onshore wind representing wind projects installed in their respective countries using consistent methods, sources, and approaches established within earlier IEA Wind Task 26 periods. The results of the analysis of land-based wind technology cost drivers are summarized in a technical report and are accessible in an online data portal. These project-level data illustrate how wind turbine technology and costs have changed from 2008 to 2016. For all countries, significant reductions of LCOE for realized projects have been observed, attributed to general technology cost improvements, technology advances that are intended to increase energy capture (taller towers and lower specific power leading to higher capacity factors) and lower financing cost.

Data on repowering of onshore wind in Denmark has been analysed and significant changes in technological characteristics could be quantified. The data set has important potential for further elaboration on key drives for repowering, which will be an important topic in the Danish wind power sector in the coming decade.

For offshore wind power, an international comparative analysis was conducted to examine the physical site characteristics, technology choices and regulatory context driving LCOE in key countries for offshore wind farms being commissioned in 2017-2018. The analysis is published in a technical report and has shown that especially the financial and regulatory environments have a greater impact than physical site characteristics. This leads to significant differences in LCOE of offshore wind in the investigated countries with Denmark having very favorable conditions.

The future prospects of wind power in terms of both cost and value have been the topic of an expert elicitation study showing leadings experts view on the development of wind power cost and technology. The results are published in a journal article, technical report and several presentations. The value of wind power in the European power system will depend not only on the future power system mix, which shows a major transition to wind and solar power, but also on the wind power technology applied to achieve future high wind power penetration levels. The options for ensuring higher value of wind power by choosing the right technologies is an important topic for both developers and policy makers.

The results of the 3rd phase of the IEA Wind TCP Task 26 are used in several activities on energy system analyses, which are dependent on using consistent wind power technology data and modelling approaches. The dissemination of the project results has contributed to involvement of external stakeholders, who use results as reference for product development and policy work. Project results are also a solid basis for further work in the 4th phase of the

IEA Wind TCP Task 26, which will continue efforts in data collection and further develop and improve analyses in the field of cost and value of wind power.

1.4 Project objectives

The purpose of the IEA Wind TCP Task 26 project was to enhance international collaboration on understanding past, present and anticipate future trends of cost and technology trends in wind power. There are three primary aspects to understanding the cost of wind energy at the present and in the future:

1. accurate data applied using transparent assumptions and methodologies to represent current market conditions and expectations;
2. analysis of historic trends and application of expert elicitation, engineering and learning models to inform potential future projections of wind energy costs
3. estimation of the value of wind energy in the broader electric system and economy in general.

The objective of the IEA Wind TCP Task 26 is to inform the above aspects by:

- Enhanced international collaboration and coordination in the field of cost of wind energy
- Updated data, analysis and understanding of on-shore wind energy cost trends and comparison among countries
- Identification of the primary offshore wind energy cost drivers and the variation of these costs among participating countries
- Collaborative journal articles summarizing and further analysing work conducted to understand trends in cost of energy
- Collaborative journal articles exploring issues related to the value of wind energy.

The 3rd phase of the IEA Wind TCP Task 26 included four work packages to address the project objectives:

- **WP1:** Update analysis of land-based wind technology cost drivers and differences among participating countries with current data
- **WP2:** Estimate cost of offshore wind energy and identify major cost drivers in each participating country
- **WP3:** Explore methods and application of methods to understand future cost of wind energy and repowering
- **WP4:** Explore methods and application of methods to understand value of wind energy in electric system

International collaboration, coordination and project management was ensured by monthly web meetings and biannual in-person meetings. The web meetings serve especially for project coordination purposes and status updates on the different work packages. The in-person meetings enable in-depth discussions of the research topics and presentation of analyses results. For all publications from the IEA Wind TCP Task 26, internal review and feedback is an important and value-adding component.

In WP1, all participants collected data representing wind projects installed in their respective countries using consistent methods, sources, and approaches established within earlier IEA Wind Task 26 periods. Data collection was carried out annually and a web-viewer was developed to facilitate both the data sharing with external parties, as well as better option and guidance for the participants to structure their data. Status updates for current matters and topics on wind power were shared at each in-person meeting. Ea Energy Analyses led the efforts of establishing the data viewer, coordinated data uploads and contributed with data collection and analyses for the Danish part.

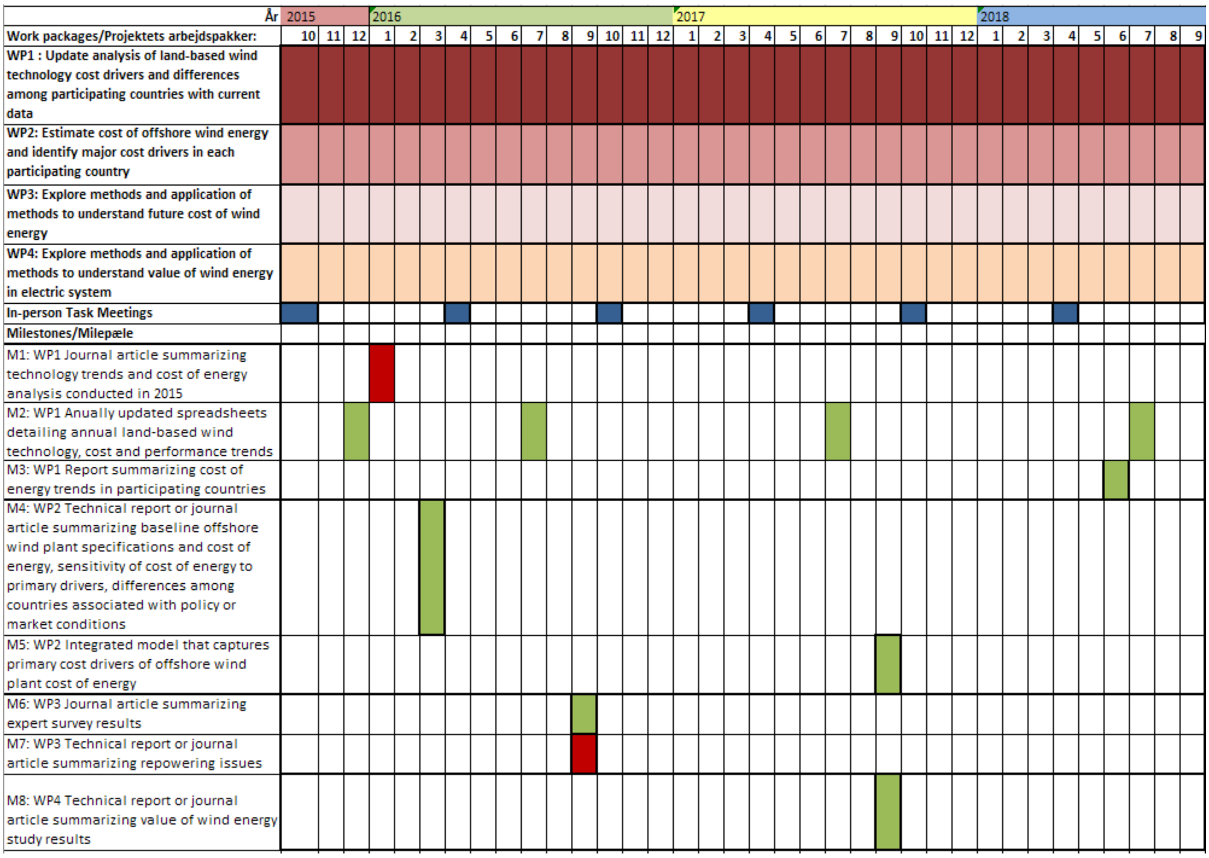
In WP2, an international comparative analysis of offshore wind examined the physical site characteristics, technology choices and regulatory context driving LCOE in key countries for offshore wind farms being commissioned in 2017-2018. The analyses was coordinated by CATAPULT (UK) who developed a model to analyse LCOE of offshore wind in different countries, and the project participants contributed with data, insights and analyses of offshore wind in the respective countries. DTU Management Engineering contributed with data and analyses on the Danish part. DTU also provided modelling of Annual Energy Production for all countries, based on an application of existing WASP models in DTU Wind.

In WP3, the results of the expert elicitation study initiated in the second phase of the IEA Wind TCP Task 26 were analysed and disseminated in various reports and journal papers. Lawrence Berkeley National Laboratory (US) led this work with input and review from the task group. DTU Management Engineering collected data on repowering projects in Denmark and assisted the European Commission's Joint Research Centre in data analyses focussing on technology trends. Furthermore, the data insights will form the background for additional analyses on key drivers in the fourth phase of phase of the IEA WIND TCP Task 26.

In WP4, Ea Energy Analyses led and carried out an analysis of the future value of wind power in the European power system using the power market model Balmorel. The scenario design for the analyses, important data assumptions and results were discussed extensively with the other participants of IEA Wind TCP Task 26.

The project achieved all of the major milestones and deliverables set forth, including all milestones, for which the Danish project participants were responsible. Certain changes of scope were implemented for selected deliverables based on the discussions in the Task group, in order to more accurately address the most relevant research areas. The key project risk was the possibility of delays in the planned activities and deliverables due to the multitude of contributors and stakeholders involved. The deliverable of a journal article based on the research in work package 1 was delayed, and is currently set for primo 2019. The University of Dublin is responsible for this deliverable and has committed to finalizing the deliverable outside of the work within phase 3 of the IEA Wind TCP Task 26 project. The scope of the deliverable was increased to cover the entire period 2008-2016. The delay did not put the overall project results at risk, since the results are communicated both in a technical report and through the web viewer. The publication of the journal article on technical performance and economic impacts of repowering has been delayed, but an article manuscript that been submitted to the journal Applied Energy and is awaiting approval. JRC is responsible for the final work towards publication.

Figure 1: Gantt-chart for project progress and milestones.



1.5 Project results and dissemination of results

1.5.1 ***WP1:*** *Update analysis of land-based wind technology cost drivers and differences among participating countries with current data*

The results of the analysis of land-based wind technology cost drivers in WP1 are summarized in the technical report *IEA Wind TCP Task 26 – Wind Technology, Cost, and Performance Trends in Denmark, Germany, Ireland, Norway, Sweden, the European Union, and the United States: 2008–2016 (Hand ed. 2018).* The data is also accessible through the web viewer, summarizing the analyses of the project level data in the respective countries (see Annex for link). The publication includes a Danish chapter on onshore wind trends in the period 2012-2016 and the findings are further analysed and compared across countries in a forthcoming paper.

Data for land based wind includes the four primary elements of cost of energy: 1) total capital investment to bring a wind plant to commercial operation; 2) annual operating expenditures over the life of the wind plant; 3) annual energy production over the life of the wind plant; and 4) cost of financing the wind plant. Accessing such data for each project installed in a participating country is often difficult or incomplete. A variety of sources may be available, and each country's data availability and quality differ. An important part of the task has been spent sharing best practices for obtaining high quality project data and defining the scope of various cost elements to improve reporting consistency among countries.

These project-level data illustrate how wind turbine technology, wind project investment and operation costs, wind plant energy production, and wind project financing costs have changed from 2008 to 2016. For all countries, significant reductions of LCOE for realized projects have been observed for the period from 2008 to 2016. The reductions are attributed to general technology cost improvements, technology advances that are intended to increase energy capture (taller towers and lower specific power leading to higher capacity factors) and lower financing cost.

The underlying data for the case of Denmark is shown on Figure 2 and Figure 3, illustrating the technology trend towards lower specific power, resulting in higher capacity factors, and contributing to reductions in LCOE. Over the same period, power market prices have been decreasing, and worsening this fact for the case of wind power, the difference between average power prices and the market value of wind power has been increasing. However, since 2016, increasing power prices and subsequently higher market value for wind power has been observed.

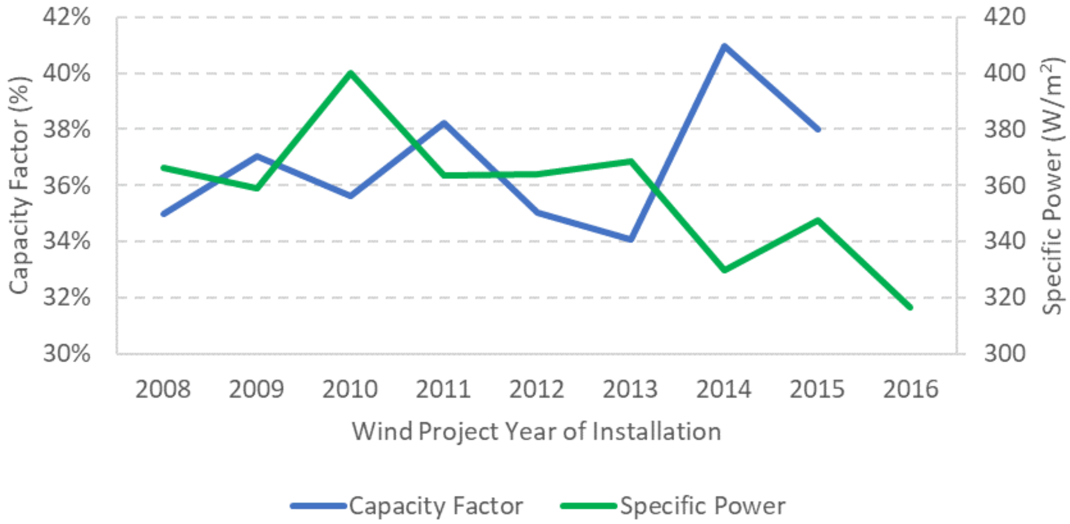


Figure 2 Specific power and capacity factors for wind projects installed in Denmark from 2008 to 2016

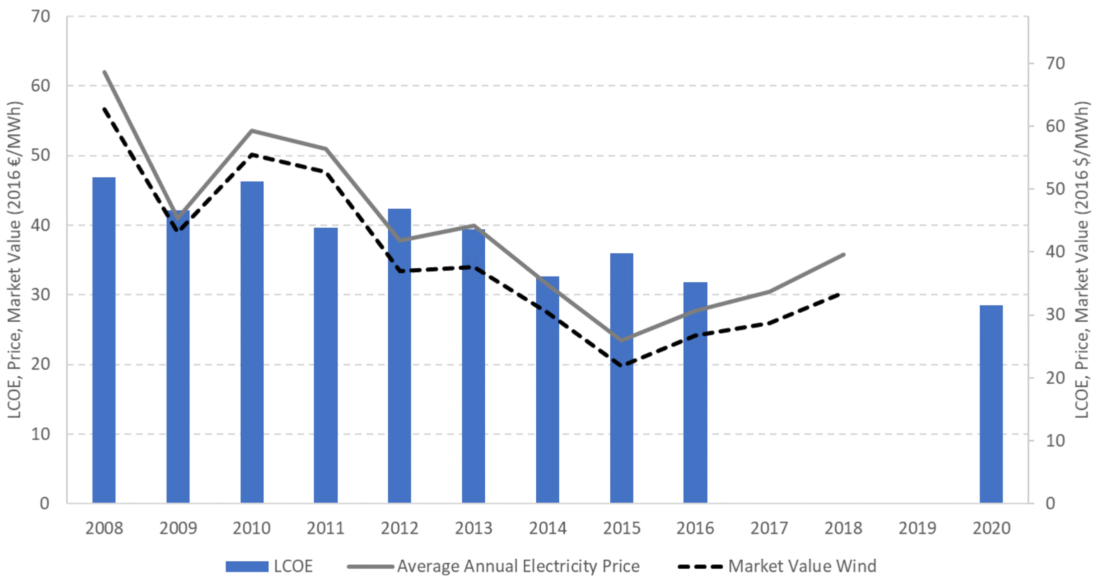


Figure 3 LCOE, average wholesale electricity price, and market value of wind[1] in Denmark from 2008 to 2016, with a projection to 2020

The web based data viewer enables easy and interactive comparison of the key parameters across countries. An example is shown for the case of specific power on Figure 4.

[1] Annual average electricity prices and market value have been converted to real 2016 terms. For 2008–2011, no specific data on hourly land-based generation was available. Therefore, the market value reported in the graph refers to the total wind generation including offshore. The value of average electricity price for 2018 refers only to Q1 (i.e., from January to March).

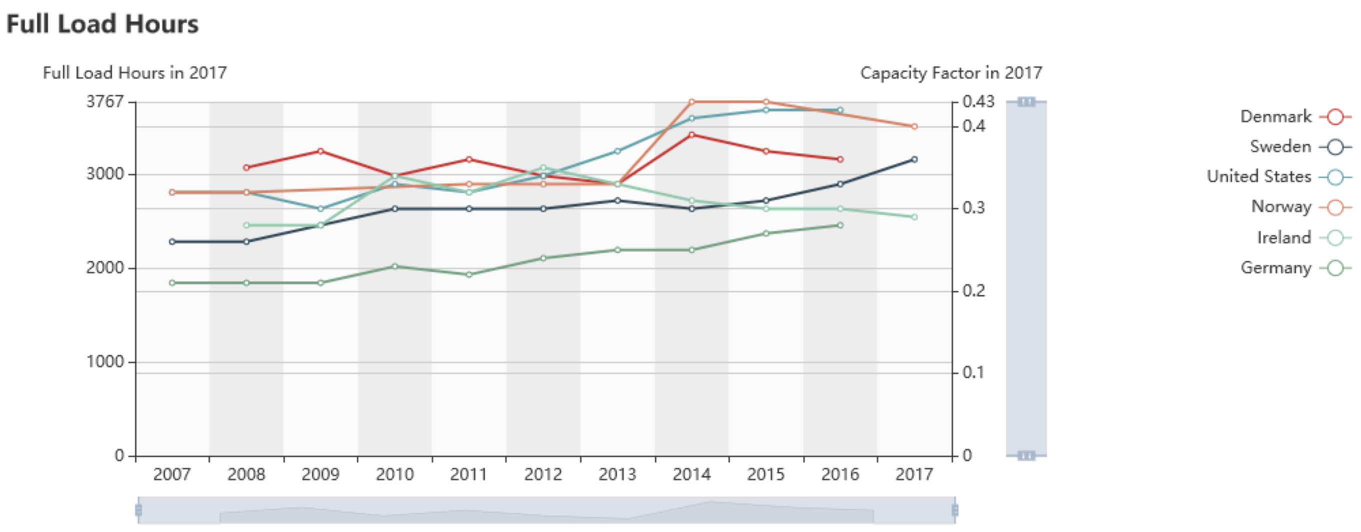


Figure 4: Example of data available in the data viewer. (Capacity factor for new projects installed in the respective years in different countries)

*1.5.2 **WP2:** Estimate cost of offshore wind energy and identify major cost drivers in each participating country*

The results of the analysis of land-based wind technology cost drivers in WP1 are summarized in the technical report *IEA Wind Task 26 – Offshore Wind International Comparative Analysis* (Noonan et. al, 2018).

The report examines the physical site characteristics, technology options, and regulatory context driving LCOE for offshore wind in relevant countries. The analyses includes LCOE modeling considering physical offshore site characteristics and regulatory difference between countries. Impacts of these factors on LCOE for offshore wind plants expecting operation in the 2017-2018 period is quantified and analysed. The range of LCOE varies significantly when all country-specific aspects are considered. Our analysis has shown that especially the financial and regulatory environments have a greater impact than physical site characteristics. This leads to significant differences in LCOE of offshore wind in the investigated countries. The spread widens particularly as transmission and part of the development cost are socialized in Denmark, Germany, and the Netherlands. Hence, they reduce LCOE for the project developer by a margin. All these factors combined make Denmark the country with the lowest offshore wind LCOE.

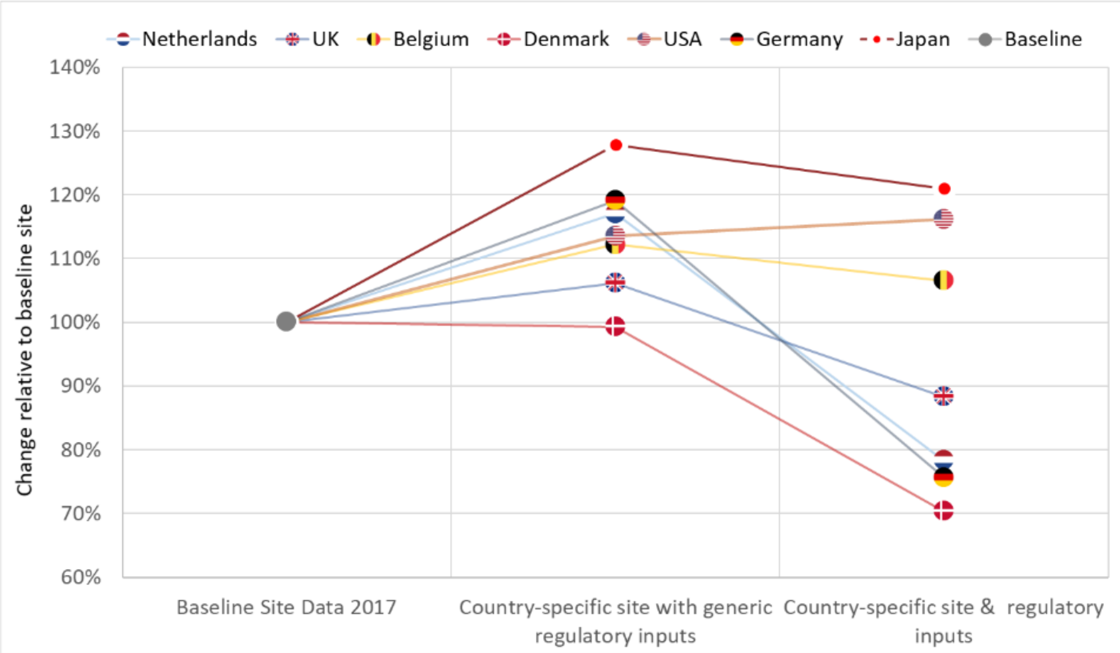


Figure 5: LCOE impact of changing country-specific parameters (Noonan et. al, 2018)

*1.5.3 **WP3:** Explore methods and application of methods to understand future cost of wind energy and repowering*

The results of the expert elicitation study initiated in phase 2 of the IEA WIND TCP Task 26 were published in a journal article in Nature Energy: *Expert Elicitation Survey on Future Wind Energy Costs* (Wiser et al. 2016a). Lawrence Berkeley Nation Laboratory released a report outlining methodology, analyses and results: *Forecasting Wind Energy Costs and Cost Drivers: The Views of the World's Leading Experts* (Wiser et al. 2016b).

The wind expert survey achieved a better understanding of future cost and performance estimates for wind technology from 2014 to 2050. Under the median scenario, experts anticipated 24–30% reductions by 2030 and 35–41% reductions by 2050 across the three wind applications studied (Figure 6).

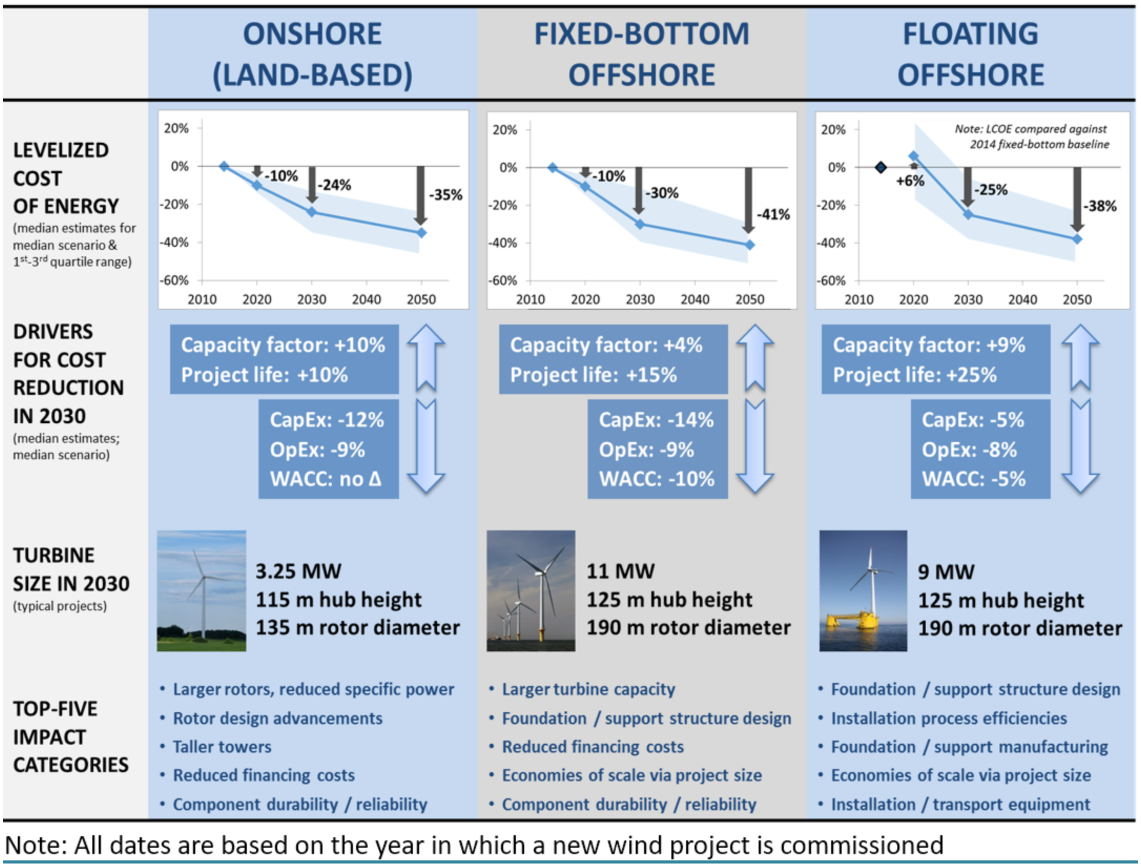


Figure 6: Expected technology and cost development for wind technology (Wiser et al. 2016b).

The results of the analysis of the technical, performance, and economic impacts of repowering are summarized in a journal article draft *Repowering wind turbines, Analysis of the effects of technology substitution in repowered wind farms – changes in wind turbine performance.* (Lacal-Arántegui and Uihlein forthcoming) submitted to Applied Energy and awaiting acceptance.

The results show that repowering in Denmark has brought about a three-time increase in rotor diameter, or nine-time increase in swept area, and twice the increase in hub height. In terms of specific power the new turbines showed a trend to lower specific powers (i.e. higher swept are regarding generator rated power) in a trend that reversed from higher to lower specific power from 2000 to 2017. Repowering involved an average increase in specific energy production by 340 kWh/m^2/yr, or 55% more. The average increase in annual energy production achieved by repowering turbines was, from 2001 to 2015, about 8.3 times the old turbine's production, from 500 MWh to 4630 MWh per year.

*1.5.4 **WP4:** Explore methods and application of methods to understand value of wind energy in electric system*

The analyses of the value of wind in the European power system is published in the technical report *IEA Wind TCP Task 26 – The Impacts of Turbine Technology on the System Value of Wind Energy in Europe* (Dalla Riva et al. 2017).

The market analyses of the future value of wind power in the European Power system showed significant importance of technology choices:

- Wind turbines with taller towers and larger rotors have higher market value
- Trade-offs between cost and value are required to assess optimal turbine choice
- The overall system perspective must be considered
- Future renewable energy policy schemes should consider value differences

The difference in market value of wind power in scenarios with different applied turbine technologies was up to 13% for Germany. The cost analyses suggest, that continuation of the current trends towards lower specific power to a level of 250 W/m2 (*likely*) compared to current average (*BAU*) would be cost effective from a system perspective. However, widespread deployment of the most ambitious technologies with specific power down to 175 W/m^2 (*ambitious*) would not be cost efficient, but should be evaluated more closely based on the varying wind conditions.

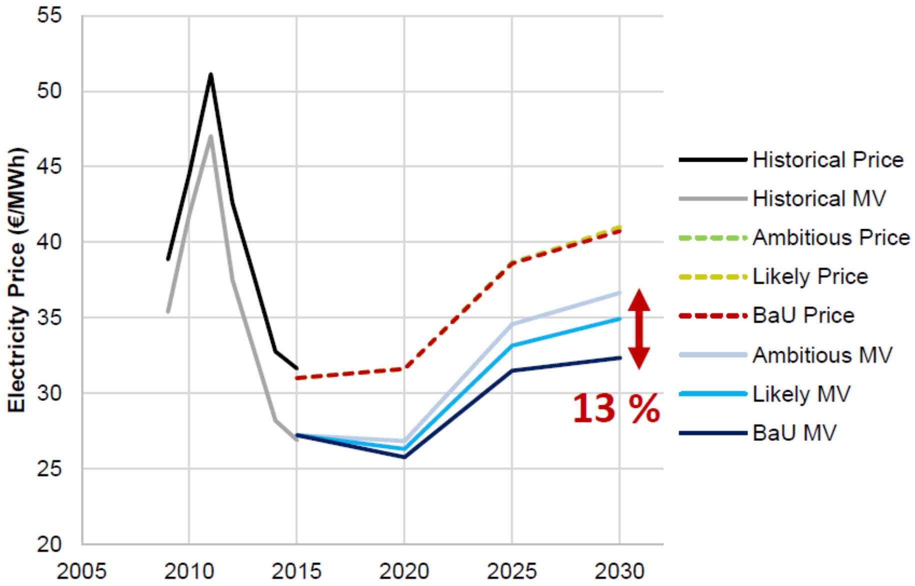


Figure 7 Electricity price and market value for wind power in Germany in different scenarios for the wind turbine technology characteristics

1.5.5 ***Dissemination activities***

The project results have been communicated, discussed and reviewed at several internal and external meetings.

External dissemination events

- Presentation of IEA Wind Task 26 report at EERA Annual Event (European Energy Research Alliance), in September 2018, Lena Kitzing, DTU Management Engineering
- *Cost and Value of wind power - Implications of wind turbine design* Presentation of WP4 at 4th Workshop on Systems Engineering for Wind Energy, János Hethey, Ea Energy Analysis, Roskilde, Denmark, September 2017, (https://www.nrel.gov/wind/systems-engineering-workshop-2017.html)
- Launch event for IEA Wind Task 26 report hosted by Denmark Technical University, more than 60 participants from industry and academia, Lyngby, Denmark, November 2017.
- Swedish industry workshop held in conjunction with Task 26 in-person meeting, June 2017.
- Expert survey panel presentation and poster at WindEurope Summit 2016, September 2016.
- *System Value of Wind Power - An analysis of the effect of wind turbine design.* Presentation at the IRPWind Conference, János Hethey, Ea Energy Analysis, Amsterdam (September 2016)
- IEA Wind Task 26 participants assisted with IEA Wind Task 11 Topical Expert Meeting on Offshore Wind Project Finance, Utrecht, Netherlands, May 2016.
- IEA Wind Task 26 highlights presented at IEA panel during EWEA Offshore Wind Conference, Paris, France, November 2015.
- Norwegian government and industry participants presented in conjunction with meeting in Oslo, Norway, October 2015.
- Launch event for IEA Wind Task 26 report hosted by Danish Wind Industry Association including many industry and academia participants, Copenhagen, Denmark, June 2015.

In-person task meetings

- Task 26 project meeting hosted by European Commission, Joint Research Centre, Petten, The Netherlands, April 2018.
- Task 26 project meeting hosted by Denmark Technical University, Lyngby, Denmark, November 2017.
- Task 26 project meeting hosted by Sweden Energy Agency, Stockholm, Sweden, June 2017.
- Joint Task 25 and Task 26 meeting focused on value of wind energy, Glasgow, UK, November 2016.
- Task 26 project meeting hosted by Fraunhofer IWES, Bremerhaven, Germany, May 2016.
- Task 26 project meeting hosted by NVE in Oslo, Norway, October 2015.

1.6 Utilization of project results

The results of the 3rd phase of the IEA Wind TCP Task 26 are used in several activities on energy system analyses, which are dependent on using consistent wind power technology data and modelling approaches.

The results can be directly applied to planning for – and promoting - energy policy objectives. Using data and analyses from the IEA Wind TCP Task 26 as background for energy system analyses feeding into political decisions regarding the future role of wind power in power systems, ensures and improved and updated basis. Thereby, the political objective of reducing greenhouse gas emissions and use of renewable energy can be achieved in a cost-effective manner. At the same time, the results from the analyses of possible technical developments and their influence on the cost of wind power could help identify areas where there will be a need of publicly funded research and development.

Utilization of results is facilitated and supported through the dissemination activities mentioned above and bilateral communication. We have discussed methodologies and data for wind power modelling with stakeholders in the industry (e.g. Vestas), who seek inspiration for future product development as well as policy stakeholders (Dansk Energi) reviewing data and methodologies used in modelling supporting the EU commissions energy policies. Options for further collaborative efforts on improving the modelling of wind and conveying the experience from e.g. the analyse in the IEA Wind TCP Task 26 are currently discussed with DTU and Dansk Energi.

Task 26 in its 4th Phase will continue to add data and analysis, develop methodologies, and enhance collaboration. The methodologies and data for wind power modelling from the 3rd phase will be further developed and an explicit work package targeting communication of state-of-the art modelling practices and data will address wind power modelling broadly in attempt to improve the basis for studies, which impact policy decisions on a global scale.

The focus on value of wind energy initiated in the 3rd phase will be further expanded, adding consistent methodologies and tracking of the value of wind power in different countries and studying technology impacts on the value of wind power. Data collection methodologies will be further developed to enable a formal framework for evaluating results from renewable energy auctions, and extrapolating these results to technology cost.

The data collection on repowering of land based wind projects from the 3rd phase will be further exploited, expanding the analyses beyond the technology focus to analyse key decisions and drivers for repowering projects.

This project was an international collaboration project, so no directly commercial use of the project results is expected, and no patents will be developed.

The project results have been openly shared among all of the institutions involved, as well as general public through the project result dissemination activities.

No PhDs have been direct part of the project. Some of the work done in relation to the repowering analysis has been utilised in one of the partner's ph.d. project (JRC). DTU Management Engineering conducts 'research-based' teaching. Hence, many of the insights gained in the collaboration projects are regularly taken up during class, in particular of courses in the MSc Sustainable Energy, where the topics of IEA Wind Task 26 are highly relevant to produce qualified candidates that enter the work-force well-informed and knowledgeable of recent international developments.

1.7 Project conclusion and perspective

Each of the work packages has contributed to knowledge creation, exchange and dissemination on the topics of cost and technology for land-based and offshore wind and application of methods to understand future cost of wind energy and value of wind energy in electric system, respectively.

Based on the successful completion of Phase 3 of the IEA Wind TCP Task 26, an extension to its' 4th Phase for the period from 2018 to 2021 has been approved by the ExCo, ensuring the continuation of the activities relating to the Cost of Wind Energy. Confirmation of Danish participation in phase 4 is pending.

The 4th phase of the project will include four work packages:

- WP1: Historical Onshore and Offshore Wind Power Costs and Drivers
- WP2: Future Onshore and Offshore Wind Power Costs and Drivers
- WP3: Exploration of the Value of Wind Power

WP1 will continue the efforts on data analyses for realised wind power projects for both onshore and offshore wind. The work package will also increase detail on modelling onshore operations and maintenance costs and exploring methods and analyses that seek to quantitatively assess the drivers of technology and plant differences among the participating countries. Based on the data collection in phase 3, an in-depth analysis on repowering in Denmark and comparison to ongoing repowering activity in other countries will be carried out.

WP2 will focus characterization and understanding of future trends in wind energy costs, based on the experience with the expert elicitation study in previous phases of the wind task. Estimates of future cost and performance of wind technology are important for understanding the potential of wind energy to contribute to the future of the electricity and other energy sectors.

Increased efforts will be put into combining the results obtained in different task activities, regarding both the current and the future status of wind power cost and performance, into a transparent set of data template that could be usable in the framework of energy system analysis, modelling and policy works. The aim is to develop guide on a state-of-the art modelling and data assumption for wind power. Up-to-date and detailed assumptions for wind power technology are a key for any analysis of targets and cost related to renewable energy at national and international energy. The network of experts and the activities of the IEA Wind TCP Task 26 will shed light onto the evolving technological and cost landscape for wind power.

WP3 will continue the focus on the value of wind power and the impacts of wind power technology on this value. The work package includes tracking of the market value for offshore and onshore wind in different countries. Following the larger exposure of wind power projects to market prices this topic receives increased attention worldwide. The activity involves a documentation of detail calculation methodologies, also in relation with issues such as curtailment and negative bidding, a compilation of data sources for IEA countries and analysis of current market value evolution for onshore and offshore wind. Furthermore, auction results will be analysed using a formalized approach to the Levelized Revenue of Electricity (LROE), which enables technology cost estimates based on bidding prices. Finally, WP3 will build on the successful analytical and modelling work on value of wind in the 3rd phase and expand the analysis with a focus on hybrid renewable power plants. Recently hybrid power plants combining renewable energy generation and low-cost storage receive increased attention, as the importance of topics on power system flexibility, power system security and reliability, and volatility of power prices increases. The value of wind and interaction between wind turbine design and storage availability on-site will be explored using scenarios modelling techniques.

Annex

Publications

Dalla Riva, A.; Hethey, J.; Vitina, A. (2017) *IEA Wind TCP Task 26 – The Impacts of Turbine Technology on the System Value of Wind Energy in Europe*. NREL/TP-6A20-7, https://community.ieawind.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=f8408b5c-d5a6-6929-f609-c5f3ee1d3e3e&forceDialog=1

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Dalla Riva, A.; Hethey, J.; Buchmann, E. (2018) *Grösser, höher, smarter?Special report in Windenergie Report Deutschland 2017*, Prof. Dr. Rohrig, Fraunhofer-Institut für Energiewirtschaft und Energiesystemtechnik IEE, 2018. http://s.fhg.de/WERD

A. Duffy et al. (2018 - forthcoming), Land-based Wind Energy Cost Trends in Selected Countries: Germany, Denmark, Ireland, Norway, Sweden, the United States and the European Union.

IEA Wind TCP Task 26 website
https://community.ieawind.org/task26/

IEA Wind TCP Task 26 Web viewer for data on land based wind
https://community.ieawind.org/task26/dataviewer

Lacal-Arántegui, R., A. Uihlein. (Forthcoming). *Repowering wind turbines, Analysis of the effects of technology substitution in repowered wind farms – changes in wind turbine performance*. Directorate General Joint Research Centre, European Commission, P.O. Box 2, 1755 ZG Petten, The Netherlands.

Lacal-Arantegui, R., J. M. Yusta, J. A. Dominguez-Navarro (2018), *Offshore wind installation: analysing the evidence behind improvements in installation time*, Journal of Renewable and Sustainable Energy Review. Volume 92, September 2018, Pages 133-145
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