International Energy Agency (IEA)
Implementing Agreement for Co-operation in the Research and Development of Wind Energy Systems (IEA Wind TCP)

Task Relaunch Proposal

Wind Energy Economics

The changing economics of wind power in high renewables futures

October 25, 2021

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1 Introduction and Scope

Wind energy is increasingly among the least-cost technology choices in many energy markets globally. This is evidenced by its growth at an average of 64 GW in new annual installed global capacity over the past five years.[1] Nevertheless, a changing generation mix, policy drivers, competing land and ocean uses, and technology innovation poses a dynamic environment for wind energy to operate in, today and into the future.

Many prescribe wind energy a central role in deep de-carbonization power sector futures[2]; however, to realize this critical role, more knowledge is needed around marginal wind energy costs as the best sites are saturated and consumed, impacts to cost and technology from increased siting constraints, and opportunities from multi-sector (e.g., electricity, fuels, molecules) integration and emerging applications. Each of these issues could have significant effects on the overall economic offering of wind energy particularly at the scales envisaged in deep decarbonization scenarios. When available, assessments of the evolving economics of wind energy are often one-off analyses that are specific to a given context; further, such insights are typically not reported on a regular basis. Traditional metrics – such as the levelized cost of energy – are useful to assess the comparative cost performance of wind energy but are increasingly supplemented by metrics that assess the economic offering (cost and value) from wind energy more holistically and in some cases at the energy system level.

In this proposed new research collaboration, we will evaluate cost and value primarily in the context of anticipated deep de-carbonization developments and emerging wind energy applications, such as the integration of wind and hydrogen production. While this work builds from past efforts of Task 26, the proposed work also reflects a considerable change. Previously Task 26 focused on understanding wind energy costs and value over time and across different jurisdictions. In this new collaboration, methods development and data collection of new wind applications (e.g., storage, hydrogen), plant configurations and operations, and associated uncertainties come into focus. We anticipate these aspects to become increasingly important as power systems change in anticipation of deep de-carbonization of the power system and the economy broadly. More specifically, we will assess how these power sector and technology developments impact the cost and value of wind power at the terawatt scales anticipated under deep decarbonization and explore what metrics are suitable for regular and more holistic reporting of cost and value trends. Our focus on future wind power applications that might shape the evolving power system include the combined use of hydrogen and wind, integrated transmission and wind energy solutions (e.g., energy islands that serve as wind plant maintenance and transmission infrastructures), and the formation of highly industrialized and large-volume supply chains (Figure 1). Further, we will evaluate the usefulness of existing and new metrics to assess the economic offering of wind power.

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[1] International Renewable Energy Agency (IRENA). 2021. "Wind Energy Data" https://www.irena.org/wind. Accessed 8/11/2021.

[2] Generally, deep decarbonization describes the (near to) exclusive use of zero-carbon resources to meet demand in the electric, transportation, industrial, and/or residential sector(s).

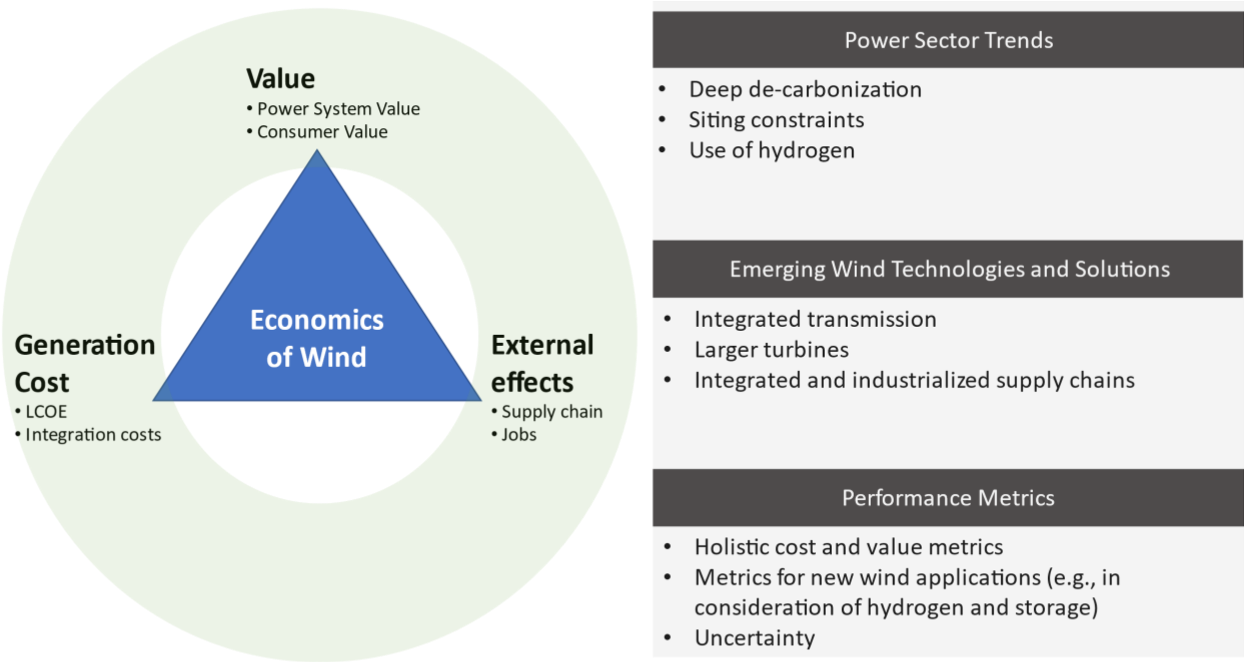

Figure 1: Research themes on the economics of wind energy

Note: "Holistic cost and value metrics" will build from the prior work of Task and further advance the two metrics in focus, Levelized Cost of Energy (LCOE) and Levelized Revenue and Value (LRVE).

Anticipating trends in the design, operations, and ownership models of wind energy under high penetration and deep decarbonization futures as well as their impact on wind energy's economic offering is essential to inform today's investment, research, and development (R&D), and energy system planning decisions. To explore these issues, the proposed new collaborative work detailed here features six work packages (WP) that each address a specific research question:

WP1: How does the design and operation of wind power plants change in a deep decarbonization future and impact the value of wind energy?

WP2: How do specific and novel technology innovation and operational trends impact the economics of wind energy?

WP3: How does uncertainty impact wind energy economics and financing?

WP4: What data and methods best inform our understanding of current and historical wind energy economics?

WP5: How does transmission infrastructure and hydrogen affect the cost and value of offshore wind energy?

WP6: How does the wind energy supply chain evolve and change in established and future markets?

By exploring these issues and tracking of wind power cost and value, this Wind Energy Economics Task significantly expands its focus on new wind applications and metrics tailored for a fundamentally different power system in the future. Further, this work supports the international community, including the IEA in understanding future wind power economics holistically. The Task also seeks to identify opportunities and intelligence on the future cost reduction potential of wind power technologies and conduct original research on how the value of wind power technologies can be increased in energy systems around the world. The work of the Task considers the full array of onshore and offshore wind power applications but focuses on megawatt scale technologies and plants. By compiling data from participating countries, analyzing differences with transparent and consistent methodologies, and disseminating our research findings to the broader IEA and international community, the Task serves as a catalyst in bringing about an abundant and clean energy future.

2 Background

In November of 2005 IEA Wind Topical Expert Meeting No. 47 was held with a focus on methodologies for estimating the cost of wind energy. This meeting demonstrated significant international interest in a Task dedicated to the analysis and evaluation of the cost of wind power systems. IEA Wind Task 26 formally began work in January 2009, with the first phase extending through 2012. A second phase of the Task officially began in October 2012 and concluded in September 2015. In the second phase of the Task, investigation of onshore wind cost of energy provided a common format to present project-level data that contributes to cost of energy calculations. Offshore balance of station model comparisons and analyses were also conducted. Further interest in the work of Task 26 resulted in a third collaboration phase extending from October 2015 to September 2018. In-depth cost comparisons of offshore wind among the participating countries were conducted and reported, and analysis of the impact of higher hub heights and lower specific power on the value of wind energy in Europe was completed. An experts' workshop on the value of wind energy was held and an expert elicitation study of future onshore and offshore wind energy costs was completed and published in the academic journal literature.

The fourth phase of the task which is coming to completion in the fall of 2021 has been similarly productive generating several high impact publications across a variety of wind energy cost topics. These accomplishments are in spite of the COVID-19 pandemic and an inability to meet in person for much of the duration of this phase of the task. Even as the Task continues to wrap up some final deliverables, a sample of key accomplishments from this period starting with the most recent first include:

- Submitted journal manuscript (*Wind Energy*) "Expert Perspectives on the Wind Plant of the Future", July 2021
- Published journal manuscript (*Joule*) "Toward global comparability in renewable energy procurement", May 2021
- Published journal manuscript (*Nature Energy*) "Expert elicitation survey predicts 37% to 49% declines in wind energy costs by 2050", April 2021
- Published journal manuscript (*WIREs Energy and Environment*) "Wind power costs driven by innovation and experience with further reductions on the horizon", March 2021
- Published journal manuscript (*Nature Energy*) "Multifaceted drivers for onshore wind energy repowering and their implications for energy transition", November 2020
- Published journal manuscript (*Applied Energy*) "Land-based wind energy cost trends in Germany, Denmark, Ireland, Norway, Sweden and the United States", November 2020
- Joint workshop co-hosted by IEA Task 26 and the International Renewable Energy Agency (IRENA) on November 14, 2019 in Bonn, Germany to explore a "Global Survey of Renewable Energy Financing Costs", including land-based and offshore wind energy technologies; resulting in funded follow-on collaborative work between Task 26 and IRENA

Throughout all phases of work completed to date, the Task has demonstrated significant and increasing value-add in the international wind energy community. Based on sustained interest in the work of the Task and a vibrant participant group, the Operating Agent (NREL) and participating members are proposing new work to that considers new wind applications, new insights on evolving economic metrics, and analysis and outcomes that examine a future where wind energy is tailored for a fundamentally different power system in the future; specifically, one where wind is at or approaching half of the electricity supply across continents and hemispheres. This work will be conducted during a period that extends from December 2021 through November 2025. This proposal details the activities and focus of the Task in the proposed new collaborative work.

We propose to conduct this work under the auspices of "IEA Wind Task 26", keeping the number from prior phases that was focused on wind energy costs and value even as we emphasize Wind Energy Economics as the title and name of the Task. The Task has established a brand around "Task 26" in the field, which is used by research and industry partners around the world. The Task has an extraordinary reach with the wind industry more broadly to inform its research and for data collection efforts. Some examples include ongoing collaboration with the International Renewable Energy Agency (IRENA) on a renewable energy finance survey (> 250 industry participants), and two broad industry surveys focused on understanding the cost and value of wind energy (> 600 industry participants), results of which were recently published in *Nature Energy*. Re-establishing this work under a new task number would be associated with non-trivial efforts from the group. We therefore propose to extend this collaborative research effort under this Task number but with a much-extended focus on emerging and highly relevant research questions and with an increased emphasis on the Task title Wind Energy Economics as opposed to the Task number.

3 Objectives and Expected Results

Increasing the global supply of low cost and abundant clean energy is a common goal of the international community and the IEA. The vibrancy of the future wind industry depends in part on a sophisticated understanding of how the cost and value of wind energy might change in the coming years and decades, especially under low carbon energy or high penetration wind scenarios futures. Additional key economic considerations include an enhanced understanding of the relationship between uncertainty and cost and value, respectively, as well as continued methods development that supports a common and holistic understanding of cost and value trends.

The proposed objectives for our new collaborative work build on but also deviate from the original Task 26 scope and objectives of the prior phases of the research collaboration. First and foremost, we seek to provide new insight and intelligence on the economics of wind energy and key drivers of historical trends. In the new task phase, Task will involve a focus on how the uncertainty associated with wind energy costs can be better characterized (WP3) and what data and methods can be developed to represent costs and the value of wind energy more holistically (WP 4). The Task also seeks to provide perspective on the potential future costs of wind energy and insight into the technology innovations and operational choices that could drive costs and value lower or higher over time (WP2). We will also analyze future cost and value more specifically in the context of deep de-carbonization scenarios and emerging wind applications (WP1). WP1 will address the value components of wind power which have become increasingly important as energy sector planners and grid operators look towards a future that could include much higher penetrations of variable renewable resources and as societies seek to transition their economies and workforces in accord with increasing supplies of renewable energy. Moreover, new wind applications, such as hydrogen and integrated transmission solutions impact both the costs and value of offshore wind and need to be considered jointly for a holistic evaluation (WP5). A new objective the Task will be the impact of global and domestic supply chain development on the cost of wind energy technologies and to identify global wind supply chain development needs (WP 6).

Throughout its work, the Task seeks to develop and maintain methodologies and data that are consistent and transparent for the international community. Such methodologies and data facilitate ongoing and future comparisons and validation of wind power analyses, research and strategic decision support.

Anticipated results from the work of the Task include:

- International collaboration and coordination in the study of wind energy costs, value, future applications, and supply chain requirements in support of a common global understanding of the status of the economic offering from wind power technologies and how they might evolve under deep de-carbonization futures
- Data that characterize and illuminate costs, value and supply chains as well as future applications of onshore and offshore wind energy and their drivers among the participating countries, providing opportunities for comparison between countries. This serves the goal of fostering future research opportunities and providing an enhanced understanding of drivers and constraints on wind power technology evolution and change
- Insights into the potential future costs and value streams of onshore and offshore wind energy, including from specific or general innovation opportunities and informed through expert elicitation, engineering analysis, and other methods; these data inform wind power technology stakeholders as well as the broader energy sector modeling and analysis community in understanding the potential role for wind power in the future energy system
- Technical reports, factsheets, journal articles, webinars and workshops that highlight key analyses and research conducted under the auspices of the Task, enabling broad-based stakeholder uptake and internalization of the diverse work activities of the Task including among policymakers and decisionmakers inside and outside of the wind power industry

The Task will seek collaboration opportunities with other IEA Tasks and external partners, building in part on ongoing dialogue during the past Task phase. Collaboration opportunities will be explored with Task 37 ("Systems Engineering") for WP 1, 2 and 3; with Task 25 ("Integration – Design and Operation of Power Systems with Wind Power") for WP 1 and WP5; and with Task 41 ("Hydrogen Data and Modeling") of the IEA Hydrogen Technology Collaboration Programme for WP 5. Recently approved (e.g., Task 50) or future new Tasks to which the team is not yet familiar with specific applicable collaboration opportunities will also be considered. In addition, we will plan to continue the informal partnership with IRENA that was formed during the past phase by exploring data sharing, review, publication and joint workshop opportunities.

4 Approach and Methodologies

The following sections provide detail on the anticipated contents and participant contributions in each of the proposed work packages. Specific country or organizational contributions to each of the work packages and estimated level of effort are summarized below and will be detailed more fully in the Task's forthcoming work plan delivered after approval of the proposed scope and formalization of commitments among the participants.

Work Package (WP) 1: How does the design and operation of wind energy change in a deep de-carbonization future and impact the value of wind energy, especially as some regions saturate their potentials amid grid value and siting considerations?

Description: Installed global wind energy capacity is approximately 0.6 TW (GWEC 2020) of which approximately 0.13 TW are operating in the U.S. today (AWEA 2021). To achieve a zero-carbon economy by 2050, as much as a five-fold increase in installed wind capacity might be needed by 2035 in the U.S. alone (Mai et al. 2021); by 2050, an installed wind capacity that is ten times today's U.S. operating capacity might be needed. In Europe, similar increases in wind energy capacity are also being considered during this period. Reaching these levels of deployment and perhaps 40-50% of our electricity supply from wind energy will require innovations in turbine and plant design as well as operational practices to enhance reliability, continue cost declines, mitigate value declines, foster social acceptance, and minimize ecological impacts. Further, changes to electricity and energy market designs might be needed to accommodate their efficient and desired functioning under high penetrations of wind energy and other renewables.

This research collaboration will utilize expert elicitation methods to inform the potential for innovations in wind plant technology, plant design, and operational practices that are critical enablers to support this significantly higher level of deployment and grid services. The expert elicitation will also explore potential market (archetype) designs that would provide sufficient incentives for new generation, reliable production, and cost efficiency. We intend that a more specific and clear understanding of how wind turbines and plants will evolve under these high deployment scenarios will be illuminated. Survey design and execution will leverage the survey pool and infrastructure developed for an earlier survey conducted in 2020 under the auspices of Task 26 and led by LBNL. The planned scope will include land-based, fixed-bottom, and floating offshore wind applications. An understanding of the key innovations and practices from the world's global experts can inform the analysis carried out under the other work packages proposed for the next Task phase, particularly WP 2 where the cost and value impact from the identified innovations will be quantified.

We expect at least one journal article highlighting the core results. Additional journal articles may be possible depending on the scope and insights of the final survey results. This work may also be coupled with spatial analysis capabilities to inform potential survey questions or to test survey responses for their potential applicability in future wind energy markets.

WP Participants List: We currently anticipate varying levels, but broad-based participation in WP1 from many countries and institutes of the research task, including representatives from Denmark, the European Commission, Germany, Ireland, Japan, Norway, Sweden, the U.K. and the U.S.

Participant Contributions: As currently scoped all Task participants will be encouraged to support the proposed dialogue exploring survey opportunities and points of focus. These discussions will be led and facilitated by the Operating Agent (NREL).

Deliverables List:
Year 2: Dissemination of the experts' survey (Lead: NREL)

Year 3: Journal article (Lead: NREL)

WP2: How do specific and novel technology innovation and operational trends impact the economics of wind energy?

Description: The cost of wind energy has declined substantially in recent years, driven largely by turbine technology improvements, plant and system design innovations, and operational efficiencies. Wind energy experts suggest that there is considerable room for additional cost declines out to 2050; however, we know relatively little about the specific turbine, plant, system, and O&M advancements needed to achieve those cost declines. Moreover, while these technological and operational advancements can reduce the cost of wind energy, they also interact with the grid-system value of wind energy – particularly under deep decarbonization scenarios – and innovations are needed to strike an adequate balance between cost and value.

This collaborative research will address these knowledge gaps through two approaches: (1) We will develop and apply engineering cost models to assess the LCOE impacts of a range of the wind technology, plant design, and operational innovations that were revealed in the Work Package 1 elicitation described above; (2) We will conduct comparative case studies (across multiple regions and grid-system archetypes) to analytically assess available solutions to increase the value of wind energy. Potential analysis questions that will be explored in this WP are the cost and value impact from increased turbine rating, hybrid plants of fixed-bottom and floating offshore wind turbines, shared export cable and offshore substations, and the effect of condition monitoring systems on O&M costs.

We expect at least one journal article highlighting the core result, focused on how to model the impact of new technologies on LCOE.

WP Participants List: We currently anticipate varying levels, but broad-based participation in WP2 from many countries and institutes of the research task, including representatives from Denmark, the European Commission, Germany, Ireland, Japan, Norway, Sweden, the U.K. and the U.S.

Participant Contributions: As currently scoped all Task participants will be encouraged to support the WP. These discussions will be co-led and facilitated by U.K, and Japan.

Deliverables List:
Year 3: Technical Report covering onshore or offshore (Lead: UK)
Year 4: Journal article highlighting the core results (Lead: Japan)

WP3: How does uncertainty impact wind energy economics and financing?

Description: The levelized cost of wind energy (LCOE) is typically calculated deterministically. However, costs are inherently uncertain because they are subject to sparse data, complex technology-cost relationships, limited foresight, and fluctuating commodity prices. This is further exacerbated by the growing share of merchant sales, which introduces additional revenue or value uncertainty for wind projects globally. If these uncertainties, including market valuation uncertainties, are not properly accounted for in the economic appraisal of wind energy assets, the conclusions drawn from cost analysis can be misleading.

In this work package, we plan to complement traditional methods for characterizing costs and work to bridge this research gap through a three-fold approach: First, we determine how project uncertainties and risks are accounted for in practice (e.g., as part of cost contingencies, the cost of capital, or government support regimes) by analyzing the results from an ongoing IEA Wind Task 26 and IRENA expert elicitation on wind energy financing costs. Second, we quantify the impact of key uncertainties and risks, including revenue uncertainty by illustrating their effect on LCOE and the cost of capital of wind energy assets. And third, we develop a model for scenario-based forecasting of wind energy financing costs. This last effort is critically important to improve forecasts of wind LCOE estimates. Financing costs have a significant impact on LCOE, yet it is arguably the LCOE input that is least known and lacks a clear methodological framework for practical use in wind cost modeling. Building on this three-fold approach we might also explore where project risks have been allocated in the past (project investors vs. the public actors) and considerations for risk allocation in future wind energy development.

We expect at least one journal article or Technical Report highlighting the core results, one focused on the exploration of how uncertainties and risks are accounted for in practice; and the second one focused on introducing a practicable method for wind cost of capital forecasting.

WP Participants List: We currently anticipate varying levels, but broad-based participation in WP2 from many countries and institutes of the research task, including representatives from Denmark, the European Commission, Germany, Ireland, Japan, Norway, Sweden, the U.K. and the U.S.

Participant Contributions: As currently scoped all Task participants will be encouraged to support the WP. These discussions will be co-led and facilitated by Denmark and the Operating Agent (NREL).

Deliverables List:
Year 2: Journal article on how wind energy uncertainties and risks are accounted for in practice (Co-Lead: Denmark and U.S.)
Year 3: OPTIONAL Journal article on a practicable method for wind cost of capital forecasting (Co-Lead: U.S. and Denmark)

WP4: What data and methods best inform our understanding of current and historical wind energy economics?

Description: Evaluation of data and methods that best inform our understanding of current and historical wind energy costs has been one of the core research activities of the Task in the past and is essential to enhance a better understanding of wind energy systems. There exists a diverse set of data and methods for calculating wind energy costs which introduce complexities and sometimes fallacies or errors in costs estimates. Presenting the evolving and diverse new methods that have arisen clearly and from a methodological viewpoint and illustrating those for the participating IEA Task countries remains necessary for consistent and equal comparisons across countries, projects, and over time. At the same time, new data are generated every day that merit continued tracking and analysis. To be sure, Task 26 has shaped and supported methods development, data availability, and broader understanding of wind energy costs and value in the international research community during past collaboration phases. However, important new challenges that have arisen and deserve continued study include a re-assessment of which metrics are adequate for considering new wind applications (such as hydrogen or storage solutions) and holistic cost evaluations (e.g., costs that are inclusive of transmission or energy island infrastructures). As the methods have evolved, the translation of this knowledge into accessible forms for students and decision-makers also remains critical.

The work within this research category focuses on three primary themes: 1) annual data updates, 2) evaluation of LCOE methods, and 3) methods validation. This WP will span onshore and offshore wind applications. The annual data updates will include technology, cost, and performance data to be collected and reported over the four-year research phase by each of the Task participants. The data will be used as inputs to evaluate country specific LCOEs using various calculation methodologies. The comparison is intended to illustrate the fallacies and complexities of different LCOE calculation methods and to integrate new wind applications and holistic considerations.

The intended product from this work is a journal article submission that details further evolution of the methods for calculating cost and value and includes relevant data collected over the majority period of the collaborations. The scope of this research is broad and is intended to span the four-year research phase, hence, the scope of work presented in the journal article will need to be narrowed and refined for the targeted journal. The analysis is expected to be conducted in years one and two with targeted journal article submission in year three.

WP Participants List: We currently anticipate varying levels, but broad-based participation in WP4 from many countries and institutes of the research task, including representatives from Denmark, the European Commission, Germany, Ireland, Japan, Norway, Sweden, the U.K. and the U.S.

Participant Contributions: As currently scoped all Task participants will be encouraged to support the WP. These discussions will be led and facilitated by Denmark.

Deliverables List:
Annual: Cost data updates (Co-lead: Denmark and U.S.)
Year 3: Journal article (Co-lead: Denmark and U.S.)

WP5: How does transmission infrastructure and hydrogen affect the cost and value of offshore wind energy?

Description: As countries around the world explore pathways to full decarbonization of the energy sector, molecule and fuel production coming into focus. At the same time, offshore wind deployment might be more and more concentrated in dedicated offshore zones, which could erode the potential value of energy produced. In consideration of these two developments, offshore wind energy could become a potentially primary source for green hydrogen production at large scale. When coupling hydrogen production with offshore wind, fundamental questions arise about cost and value optimal designs. For instance, electrolysis could be conducted either onshore or offshore, co-located with individual offshore wind farms or as part of larger clusters. Moreover, whether and how to interconnect fuel or molecule production processes with the broader power grid has significant potential implications for cost and value. Of specific interest and relevance is the potential revenue gain from adding hydrogen producing infrastructure at different locations, the relative cost necessary to realize hydrogen sales, and implications for transmission and interconnection planning at sea and on land.

Exploring the impact of combined hydrogen and transmission infrastructure development on the cost and value of wind energy is a new addition to the Task and fills an important gap in academic and applied research. Because of the novelty of this research field, a scenario approach will be taken, which explores the relative impact of different hydrogen and transmission configurations. This research collaboration will build on existing cost and value modeling tools among the participating members for technical-economic assessment. By amending considerations for hydrogen use under different transmission and market configurations, new quantitative insights will be generated to inform potential tradeoffs for policymakers and planners. We expect to be able to present comparable findings on cost and value impact of hydrogen infrastructure choices across participating countries.

Specific findings from individual and collaborative inquiries in this domain will be presented in at least one technical report or an academic journal article.

WP Participants List: We currently anticipate varying levels, but broad-based participation in WP2 from many countries and institutes of the research task, including representatives from Denmark, the European Commission, Germany, Ireland, Japan, Norway, Sweden, the U.K. and the U.S. Explicit contributions will be detailed more fully in the Task Work Plan to be developed pending the approval of the Extension Proposal.

Participant Contributions:
As currently scoped all Task participants will be encouraged to support the WP. These discussions will be led and facilitated by Denmark.

Deliverables List:
Year 2: Technical report or journal article on the cost and value considerations for offshore wind and hydrogen coupling (Lead: Denmark)

WP6: How might the wind energy supply chain evolve and change in established and future markets?

Description: Wind technology has grown rapidly, both in market penetration and turbine size. The supply chain has kept pace with global demand to date. However, potential scale-up of demand anticipated under deep decarbonization scenarios might bring a tipping point when supply chains are no longer able to deliver. Innovation and additional investment beyond current levels might be needed to enable further growth. The probability of such a scenario is increasing as many major economies have formulated ambitious wind energy targets and strategies (e.g. EU NECPs, EU Offshore Renewable Energy (300 GW by 2050), China's 14th 5-year plan) requiring the scaling of global supply chains and potentially increased cross-country collaboration in order to prevent bottlenecks. Moreover, many global wind energy supply chains need to develop new capabilities in the transportation and lifting of components for the next generation of onshore and offshore wind turbines. Further, higher levels of anticipated wind energy production suggest increased demand for automation and more consistent fabrication processes.

This research collaboration will identify key enabling supply chain technologies and map them to markets where needs for those technologies might likely arise. We will also examine the potential impact on total wind energy costs that these infrastructure investments could have. In a possible subsequent step, we may estimate the future value (e.g., expected jobs, sales volume) created within a region considering the expected onshore and offshore wind capacities by 2030 and 2050. More specifically, for a given region we may consider the following approach: First, we analyze current wind deployment and respective turbine models in use. Second, we identify the subcomponents (blade, bearings, pitch system, generator, support structure, etc.) of the turbine models and their manufacturing location, building on data published by certification bodies, EPDs and others. Third, we use the Task's knowledge on costs (capital expenditure shares at the component level) to identify the value created within a region or through a specific Original Equipment Manufacturer. As an optional final step, we might expand to a forward looking perspective, providing estimates on future (e.g., 2030/2050) regional value creation and assembly needs.

We expect at least one technical report focusing on the offshore wind supply chain sector. Another report might assess the onshore sector, yet a simplified approach would be needed given the amount of onshore turbine models and the associated data gaps.

WP Participants List: We currently anticipate varying levels, but broad-based participation in WP2 from many countries and institutes of the research task, including representatives from Denmark, the European Commission, Germany, Ireland, Japan, Norway, Sweden, the U.K. and the U.S. Explicit contributions will be detailed more fully in the Task Work Plan to be developed pending the approval of the Extension Proposal.

Participant Contributions: As currently scoped all Task participants will be encouraged to support the WP. These discussions will be led and facilitated by the EU.

Deliverables List:
Year 2: Inventory of supply chain and port capabilities (Lead: EU)
Year 3: Technical Report (Lead: EU)
Year 3: OPTIONAL Forward looking journal article exploring supply chain vulnerabilities and opportunities with projected deployment through 2030/2050

5 Time Schedule with Key Dates

To maintain continuity of the Task's work and participation, we propose to initiate the Task on December 1, 2021, and to continue, in principle, for a period of four years, through November 30, 2025. At the conclusion of this four-year period, two or more Participants, acting in the IEA Wind Executive Committee, have the option of extending the Task for a period to be determined at that time. Any extension shall apply only to the Participants who agree to the extension.

The proposed schedule for the activities and deliverables described in Section 4 of this document are shown in Figure 2. Details include planned meetings, OA administrative deliverables and deliverables and activities associated with each of the specific work packages.

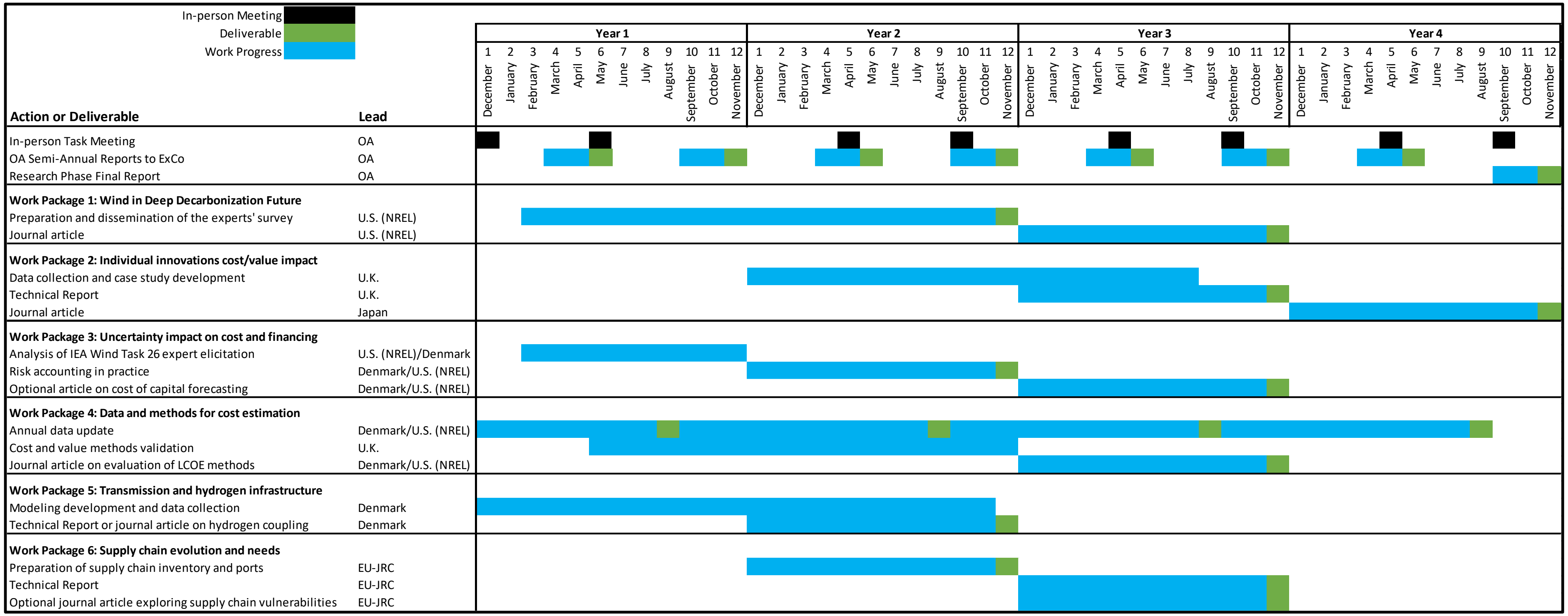

Figure 2. Proposed Work Plan Chronogram

6 Reports, Deliverables, and Dissemination of Results

Reports will be accessible through the Task website, and any other Participant web-based dissemination mechanism at the discretion of the Participant. In addition, to the committed deliverables, all participants are encouraged to seek opportunities to disseminate results through conferences, webinars, or other means. Publications created by participants in association with the Task will be posted or linked from the IEA Wind website assuming permission is granted by the appropriate publishing organization.

Table 1. Planned Deliverables and Schedule

No.	Deliverable	Month Due
D1-D4	OA Annual Reports to ExCo	7, 19, 31, 43
D5	OA Research Phase Final Report	48
D6	WP 1: Dissemination of the experts' survey (Lead: NREL)	24
D7	WP 1: Submitted Journal article (Lead: NREL)	36
D8	WP 2: Technical Report covering onshore or offshore (Lead: UK)	36
D9	WP 2: Journal article highlighting the core results (Lead: Japan)	48
D10	WP 3: Journal article on how wind energy uncertainties and risks are accounted for in practice (Co-Lead: Denmark and U.S.)	24
D11,12,13,14	WP 4: Annual Cost data updates (Co-lead: Denmark and U.S.)	9, 21, 33, 45
D15	WP 4: Journal article (Co-lead: Denmark and U.S.)	36
D16	WP 5: Technical report or journal article on the cost and value considerations for offshore wind and hydrogen coupling (Lead: Denmark)	24
D17	WP 6: Inventory of supply chain and port capabilities (Lead: EU-JRC)	24
D18	WP 6: Technical Report (Lead: EU)	36

7 Methods of Review and Evaluation of the Work Progress

The Operating Agent will consult and monitor each project participant on the progress made in relation to the plan through monthly web-meetings and bi-annual in-person meetings. Initially, more frequent communication will occur to assure that the full work plan document is completed and up to date with descriptions of each party's contribution. Based on input from these regular consultations, a status report which summarizes the progress of each work package will be developed and submitted to the IEA Wind Executive Committee. Changes to the work plan will be managed on an as needed basis pending potential changes in participating personnel or availability.

8 Obligations and Responsibilities

This Task requires collaboration among all participants as well as contributions of technical work that are conducted independently. The obligations of the Operating Agent and the Participants are described more broadly below. Data and products developed through the Task will be available equally to all participants. Data and products of the Task will not be available externally until completion of the Task or by agreement of the participants. New entrants will be encouraged throughout the Task and will be obligated to contribute to the cost-share for the year in which the Task is joined. Participants who wish to withdraw from this Task after it begins will be obligated to contribute their share of the cost-share for the year in which they wish to withdraw.

Operating Agent

In addition to the responsibilities enumerated in Article 4 of the IEA Wind Agreement the Operating Agent shall:

- Prepare a detailed Program of Work in co-operation with the other Participants;
- be responsible for organizing meetings of representatives designated by Participants;
- be responsible for the performance of the Task and report annually to the Executive Committee on the progress and the results of the work performed under the Program of Work;
- provide to the Executive Committee, within six months after completion of all work defined in the Work Program, a final report summarizing the findings of the Task for its approval and transmittal to the Agency.

The responsibilities of the Operating Agent relate to the international co-operation in the Task. The Operating Agent shall not be liable for the national efforts of the Participants even if the national efforts are in relation to the Task.

Participants

In addition to any obligations listed in the IEA Wind Agreement, the following obligations and responsibilities are to be adhered to by the participants of the project:

- Each Participant shall bear its own cost for the scientific work, including travel expenses.
- The host country shall bear the costs of workshops and meetings of experts.
- The total costs of the Operating Agent shall be borne jointly and in equal shares by the Participants.
- Each Participant shall transfer to the Operating Agent its annual share of the costs in accordance with a time schedule to be determined by the Participants, acting in the Executive Committee.
- Each Participant shall submit presentation materials and reports presented at the Task meetings to the Operating Agent for posting on the Task website, the format of which shall be agreed upon by the Participants.
- Each Participant will participate in editing and review of Task articles and the Final Report. In addition to the activities described in the Work Packages in Section 4, each participating country is conducting related work. The planned effort from each participating country is estimated in Table 2. The portions denoted "Approximate Direct Contribution" indicates the effort taken specifically for this Task while the column "Approximate Indirect Contribution" indicates the effort for related work that will partly support this Task. The Task officially begins December 1, 2021 and will conclude November 30, 2025.

Table 2. Planned effort from each Participant

Expected Role						
	WP1	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**
Denmark	Contributor	Contributor	Co-Lead	**Co-Lead**	**Co-Lead**	Contributor
EU JRC	Contributor	Contributor	Contributor	Contributor	Contributor	**Co-Lead**
Germany	Contributor	Contributor	Contributor	Contributor	Contributor	Observer
Ireland	Observer	Observer	Contributor	Contributor	Observer	Contributor
Japan	Contributor	**Co-Lead**	Contributor	Contributor	Contributor	Contributor
Norway	Contributor	Contributor	Contributor	Contributor	Contributor	Contributor
Sweden	Observer	Observer	Observer	Contributor	Observer	Observer
UK	Contributor	Contributor	Contributor	Observer	Contributor	Contributor
US	**Lead**	**Co-Lead**	**Lead**	**Co-Lead**	**Co-Lead**	**Co-Lead**
Approximate Direct Contribution (Person Months)						
	WP1	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**
Denmark	1.0	3.5	5.0	6.0	6.0	1.3
EU JRC	0.0	0.0	0.0	4.0	0.0	8.0
Germany	1.0	1.5	1.5	1.5	1.5	0.5
Ireland	0.5	0.0	3.0	3.0	0.0	6.0
Japan	1.0	4.0	2.0	2.0	1.0	1.0
Norway	2.0	2.0	1.5	1.5	1.0	1.0
Sweden	0.0	0.0	0.0	1.3	0.0	0.0
UK	0.5	0.5	0.5	0.2	0.5	0.5
US	10.2	4.7	5.5	10.8	3.5	6.9
Total (Person Months)	**16.2**	**16.2**	**19.0**	**30.3**	**13.5**	**25.2**
Approximate Value (USD)	**$518,400**	**$518,400**	**$608,000**	**$968,000**	**$432,000**	**$804,800**
Approximate Indirect Contribution (Person Months)						
	WP1	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**
Denmark	2.5	4.5	5.0	5.0	6.0	3.3
EU JRC	0.0	0.0	0.0	0.0	0.0	0.0
Germany	1.0	3.0	1.0	7.0	3.5	0.0
Ireland	0.0	0.0	0.0	3.0	0.0	0.0
Japan	0.0	8.0	4.0	4.0	0.0	0.0
Norway	2.0	6.0	2.0	3.0	2.0	3.0
Sweden	0.0	0.0	0.0	0.0	0.0	0.0
UK	0.3	0.3	0.3	0.1	0.3	0.3
US	11.2	19.2	7.0	18.4	8.0	9.4
Total (Person Months)	**17.0**	**41.0**	**19.3**	**40.5**	**19.8**	**15.9**
Approximate Value (USD)	**$542,400**	**$1,310,400**	**$616,000**	**$1,296,000**	**$632,000**	**$508,800**
Combined Total (Person Months)	**33.2**	**57.2**	**38.3**	**70.8**	**33.3**	**41.1**
Combined Total (USD)	**$1,060,800**	**$1,828,800**	**$1,224,000**	**$2,264,000**	**$1,064,000**	**$1,313,600**

9 Funding

This Task will be both “cost shared” and “task-shared” in that the costs of the Operating Agent shall be borne jointly and in equal shares by the participating IEA Member Countries. The cost of the scientific work, including travel expenses, will be borne by each participant as estimated in Table 3 above.

The Operating Agent is the National Renewable Energy Laboratory of the U.S. This is not the Contracting Party, but it accepts the rights and powers, and will carry out the obligations and functions of the Operating Agent as provided in the Agreement. Eric Lantz a career employee and manager at NREL will serve as the Operating Agent.

10 Budget Plan

The total costs of the Operating Agent for coordination, management, and reporting are estimated to be $400,000 over a projected four-year period and may not exceed this level except by unanimous agreement of the Participants, acting in the Executive Committee. Table 4 shows the estimated annual costs for these activities; assuming 9 participants, the annual fee will be $11,100. If additional participants are identified, the scope of work for the Operating Agent will be re-assessed with Participant recommendations to be provided to the Executive Committee.

Table 3. Operating Agent Costs

	Person-months	USD	USD/yr	Euro	Euro/yr
Meetings, coordination work	3.75	$120,000	$30,000	€ 102,000	€ 25,500
Reporting (including Publications)	6.25	$200,000	$50,000	€ 170,000	€ 42,500
Travel costs	n/a	$60,000	$15,000	€ 51,000	€ 12,750
Other costs (Editing/Design)	0.63	$20,000	$5,000	€ 17,000	€ 4,250
TOTAL	**12.5**	**$400,000**	**$100,000**	€ 340,000	€ 85,000

Note: Euro denominations based on 0.85 Euro for 1.00 USD

11 Management of Task

The Task's management structure is designed to conduct the work packages as described in Section 4 of this document according to the planned scope and budget. The Operating Agent will coordinate with the participants to: 1) define the scope and estimated labor for each country's contribution, for inclusion in the work plan; 2) establish a communication method and procedure for collaboration to conduct the work; 3) monitor progress through annual reporting; 4) conduct plenary meetings at approximately 6-month intervals at which progress is evaluated by all participants.

To facilitate the required collaboration, regular (e.g., monthly or bi-monthly) web meetings will be conducted through most of each year. The existing Task website will be updated to contain the data and models developed through the Task. E-mail will be the primary method of communication among participants. Meeting notes will be distributed to all participants after each of the plenary meetings. The semi-annual status reports that are prepared for the Executive Committee will also be distributed to the participants. All Task documentation and content will be available on the IEA Wind website.

12 Organization

See detailed work plan in Section 4.

13 Information and Intellectual Property

(a) **Executive Committee's Powers**. The publication, distribution, handling, protection and ownership of information and intellectual property arising from activities conducted under this Annex, and rules and procedures related thereto shall be determined by the Executive Committee, acting by unanimity, in conformity with the Agreement.

(b) **Right to Publish.** Subject only to copyright restrictions, the Annex Participants shall have the right to publish all information provided to or arising from this Task except proprietary information.

(c) **Proprietary Information.** The Operating Agent and the Annex Participants shall take all necessary measures in accordance with this paragraph, the laws of their respective countries and international law to protect proprietary information provided to or arising from the Task. For the purposes of this Annex, proprietary information shall mean information of a confidential nature, such as trade secrets and know-how (for example computer programmes, design procedures and techniques, chemical composition of materials, or manufacturing methods, processes, or treatments) which is appropriately marked, provided such information:

  (1) Is not generally known or publicly available from other sources;

  (2) Has not previously been made available by the owner to others without obligation concerning its confidentiality; and

  (3) Is not already in the possession of the recipient Participant without obligation concerning its confidentiality.

It shall be the responsibility of each Participant supplying proprietary information, and of the Operating Agent for arising proprietary information, to identify the information as such and to ensure that it is appropriately marked.

(d) **Use of Confidential Information.** If a Participant has access to confidential information which would be useful to the Operating Agent in conducting studies, assessments, analyses, or evaluations, such information may be communicated to the Operating Agent but shall not become part of reports or other documentation, nor be communicated to the other Participants except as may be agreed between the Operating Agent and the Participant which supplies such information.

(e) **Acquisition of Information for the Task.** Each Participant shall inform the other Participants and the Operating Agent of the existence of information that can be of value for the Task, but which is not freely available, and the Participant shall endeavour to make the information available to the Task under reasonable conditions.

(f) **Reports on Work Performed under the Task.** Each Participant and the Operating Agent shall provide reports on all work performed under the Task and the results thereof, including studies, assessments, analyses, evaluations and other documentation, but excluding proprietary information, to the other Participants. Reports summarizing the work performed and the results thereof shall be prepared by the Operating Agent and forwarded to the Executive Committee.

(g) **Arising Inventions.** Inventions made or conceived in the course of or under the Task (arising inventions) shall be identified promptly and reported to the Operating Agent. Information regarding inventions on which patent protection is to be obtained shall not be published or publicly disclosed by the Operating Agent or the Participants until a patent application has been filed in any of the countries of the Participants, provided, however, that this restriction on publication or disclosure shall not extend beyond six months from the date of reporting the invention. It shall be the responsibility of the Operating Agent to appropriately mark Task reports that disclose inventions that have not been appropriately protected by the filing of a patent application.

(h) **Licensing of Arising Patents.** Each Participant shall have the sole right to license its government and nationals of its country designated by it to use patents and patent applications arising from the Task in its country, and the Participants shall notify the other Participants of the terms of such licences. Royalties obtained by such licensing shall be the property of the Participant.

(i) **Copyright.** The Operating Agent may take appropriate measures necessary to protect copyrightable material generated under the Task. Copyrights obtained shall be held for the benefit of the Annex Participants, provided however, that the Annex Participants may reproduce and distribute such material, but shall not publish it with a view to profit, except as otherwise directed by the Executive Committee, acting by unanimity.

(j) **Inventors and Authors.** Each Annex Participant will, without prejudice to any rights of inventors or authors under its national laws, take necessary steps to provide the co-operation from its inventors and authors required to carry out the provisions of this paragraph. Each Annex Participant will assume the responsibility to pay awards or compensation required to be paid to its employees according to the law of its country.

14 List of Potential Participants

The individuals below have expressed interest in participating in the Task Relaunch.

Expert Participants	Organization
Denmark	
János Hethey	EA Energy Analyses
Alberto Dalla Riva	EA Energy Analyses
Lena Kitzing	Denmark Technical University (DTU)
European Commission – Joint Research Centre	
Thomas Telsnig	Joint Research Center (JRC)
Germany	
Silke Lüers	Deutsche WindGuard
Volker Berkhout	Fraunhofer Institute for Energy Economy and Energy System Technology (IEE)
Ireland	
Fiona Devoy McAuliffe	University College Cork
Shadi Kalash	Sustainable Energy Authority of Ireland
Forest Mak	Sustainable Energy Authority of Ireland
Japan	
Yuka Kikuchi	University of Tokyo
Netherlands	
Iratxe Gonzalez Aparicio	TNO
Norway	
Magnus Wold	Norwegian Water Resources and Energy Directorate
Sweden	
Jonas Bjärnstedt	Swedish Energy Agency (SEA)
UK	
Gavin Smart	Offshore Renewable Energy (ORE) Catapult
USA	
Eric Lantz	National Renewable Energy Laboratory (NREL)
Philipp Beiter	National Renewable Energy Laboratory (NREL)
Tyler Stehly	National Renewable Energy Laboratory (NREL)
Ryan Wiser	Lawrence Berkeley National Laboratory (LBNL)
Joe Rand	Lawrence Berkeley National Laboratory (LBNL)