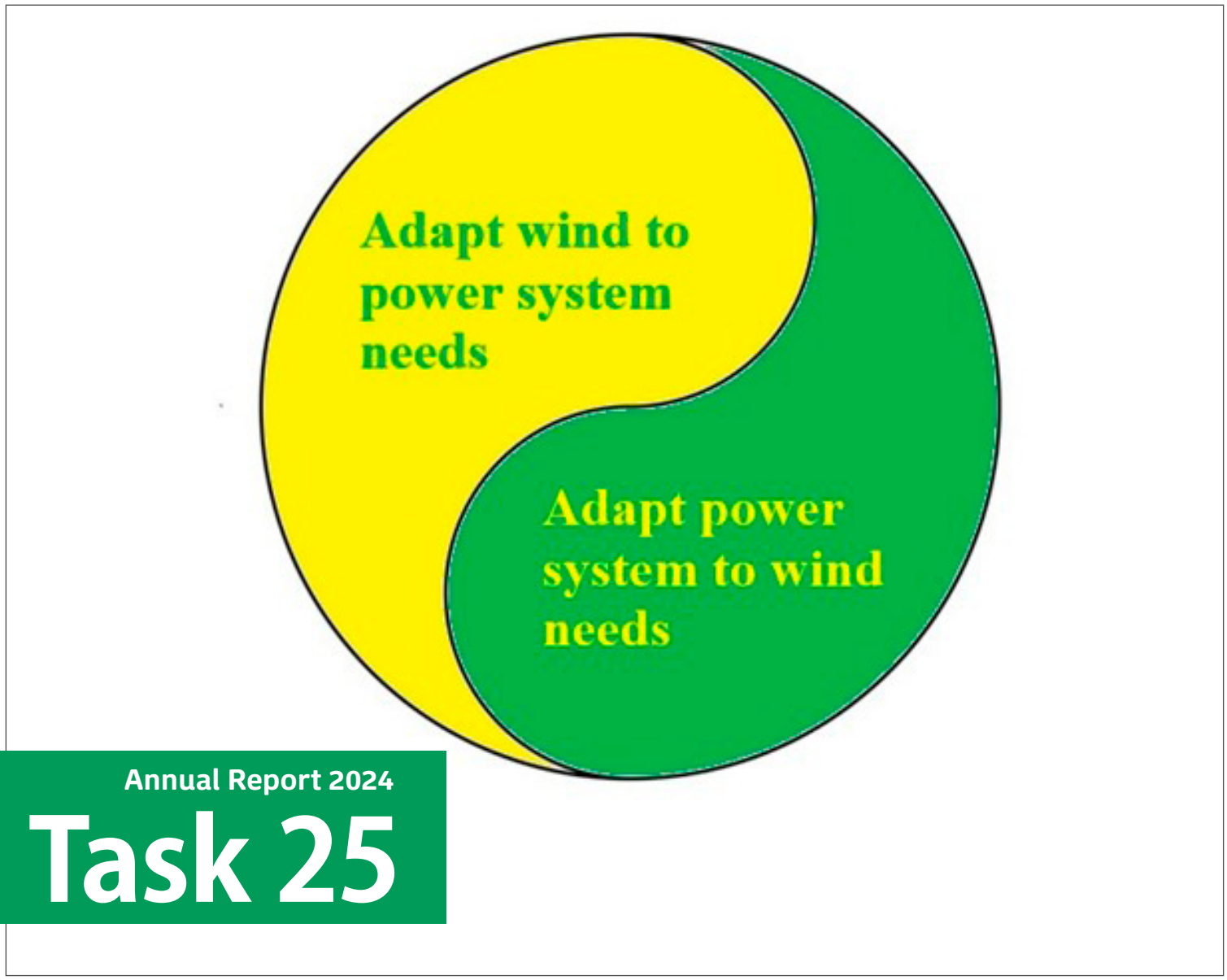

Annual Report 2024

Task 25

Photo: *Wind adapting to the power system and the power system adapting to wind - a pathway to a cost-effective reliable power system.* *(Source: [2].)*

Design and Operation of Energy Systems with Large Amounts of Variable Generation

Author: Hannele Holttinen, Recognis

Energy system impact studies are important for defining targets for wind and other variable renewable energy, and for defining future decarbonising pathways.

Task 25 has worked towards commonly accepted methodologies to be applied in system impact studies for power and energy systems dominated by wind and solar energy. International collaboration is key to harvest knowledge from both practical experience and studies in different countries, in the evolving power and energy systems of the future.

Task 25 ended in 2024 after completing its sixth phase. A follow-up task was approved in November 2024, Task 25/63, for a four year term (2025-2028). Updating Recommended Practices for Wind/PV Integration Studies was the main effort for the Task in 2024. In addition, participants of Task 25 published joint articles on Grand Challenge Grid (Grand challenges of wind energy science – meeting the needs and services of the power system), Dynamic Line Rating Models and Their Potential for a

CostEffective Transition to Carbon-Neutral Power Systems, and Estimating wind energy future emission reductions towards carbon neutral energy systems.

Task 25 brings best practices from energy system study methods as well as experience and study results to member countries and a wider audience through IEA, IRENA, Global Power System Transformation (G-PST) and Energy System Integration Group (ESIG). On top of these international network stakeholders, the system operators are the main target group of Task 25; they are joining Task 25 work directly (from Denmark, Italy, France) and as observers (Germany, Finland, Spain, Japan, Sweden, the UK).

Introduction

Task 25 work started in 2006 to tackle the differences that were seen in results from studies on wind integration including cost of integration. By analysing the multitude of studies investigating power system impacts of wind power, most differences were explained and best practices for system studies drawn. Since then, a convincing amount of experience from wind integration have emerged and wind integration studies have become energy system impact studies for high shares of wind and solar energy.

Targets for wind and solar are reaching higher and higher shares of demand. The concerns regarding variable generation are shifting from costs of integration to costs of power system inflexibility. Assessing the impacts in practice means comparing costs and reliability of alternative scenarios for power and energy systems.

International collaboration remains key to learn from both experience and

COUNTRY/SPONSOR	INSTITUTIONS
Canada	University of Victoria (M.McPherson); University Laval (A.Rabiee); NRCan
China	SGERI (Wang Yaohua, Liu Jun)
Denmark	DTU Wind (Nicolaos Cutululis); Transmission System Operator Energinet.dk (Antje Orths)
Finland, OA*	Recognis Oy (H. Holttinen); VTT Technical Research Centre of Finland (N. Helistö, J. Kiviluoma)
France	EdF R&D (E. Neau); Transmission System Operator RTE (T. Heggarty); MinesTech (G. Kariniotakis)
Germany	Fraunhofer IEE (J. Dobschinski); FfE (S. vanRoon, A. Guminski);
Ireland	UCD (D. Flynn); SEAI (J. McCann); Energyreform (J. Dillon);
Italy	Transmission System Operator Terna (Enrico Maria Carlini)
Japan	Kyoto University (Y. Yasuda) *, CRIEPI (R. Tanabe)
Norway	NTNU (Magnus Korpås); SINTEF (JO Tande, Til Kristian Vrana); NVE (J. Cabrol)
NL	TUDelft (Simon Watson); TNO (Germán Morales-España)
Portugal	LNEG (Ana Estanqueiro), INESC-TEC (Bernardo Silva)
Spain	University of Castilla La Mancha (Emilio Gomez); Comillas Pontifical University (Andrés Ramos Galán)
Sweden	KTH (Lennart Söder)
UK	Imperial College (G. Strbac), ORE Catapult (J. Nwobu)
USA	NREL (B. Frew), ESIG (D. Lew, J. Matevosyan); DoE (J. Fu)
WindEurope	European Wind Energy Association (Vidushi Dembi, Vasiliki Klonaris)
	Professor Yasuda affiliation moved to ISEP in April 2024.

Table 1. *Countries Participating in Task 25*

studies of energy systems with high shares of variable generation in different countries, in the evolving power and energy systems of the future. Task 25 ended in 2024 after its sixth term (2021-24). The main stakeholders have been the system operators, joining Task 25 directly and as observers. IEA and IRENA have been frequent observers to Task 25 meetings, and work in other relevant international networks, Global Power System Transformation (G-PST) and Energy System Integration Group (ESIG) and ENTSO-E are closely followed.

In addition, Task 25 is active in inter-TCP collaboration: solar integration (PVPS TCP Task 14), and flexibility needs in future (Hydro TCP Task 9; Bioenergy Task 44) are important common topics for system studies, as well as transmission planning (ISGAN WG6). Task 25 joined the IEA TCP Coordination Group on Flexibility in 2024.

Progress and Achievements

Through Task meetings, an international forum has been established for member countries including their Transmission System Operators (TSOs) to exchange knowledge of and experiences with power and energy system planning and operations with large amounts of wind and solar energy (Table 1). The two meetings in 2024 were mainly in-person, however allowing for online participation.

The spring meeting was hosted by SEAI in Dublin, Ireland. This was in conjunction of Topical Expert Meeting on Net Zero Studies and had one day meeting jointly with Task 53 Economics. The fall meeting was hosted by NRCan and University of Victoria in Victoria, Canada, with observers from IEA Hydro Task 9. A public workshop was organized in conjunction with the Task meeting, with two Task 25 sessions: IESVic & EMH Energy Dialogue Symposium *uvic.ca/research/centres/iesuic/news-events/current/iesuic-and-emh-energy-dialogue-symposium.php*

Task 25 is highlighting the evolving best practices for system impact studies. Recommended Practices RP16 was updated to Edition 3 [1], including recommendations for wind and solar dominated power systems (Figure 1). The main challenges are 1) power system stability due to the inverter based, non-synchronous grid interface, and 2) balancing due to the varying resources.

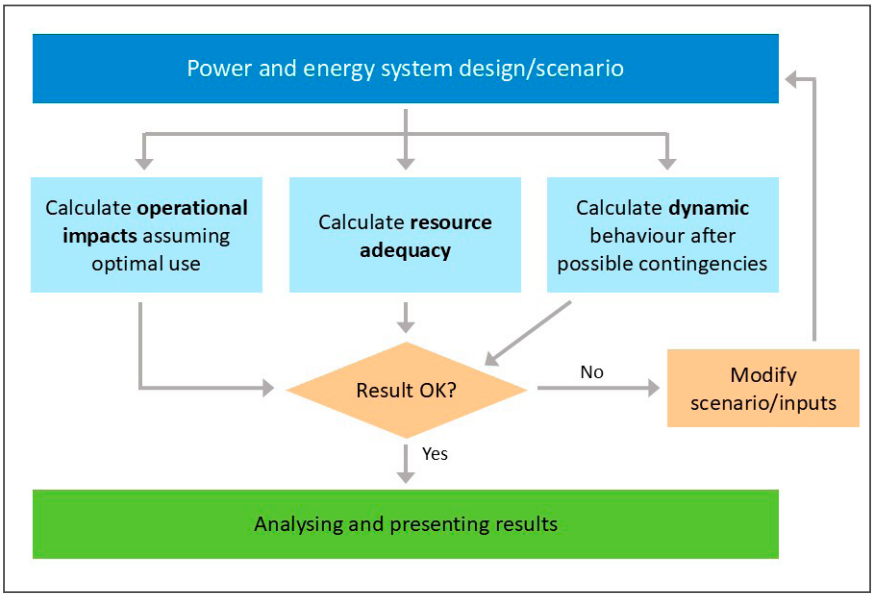

Figure 1. *Recommended Practices for wind/solar integration studies follow a flow chart, including three main parts of an integration study: impacts on operation, adequacy and dynamics of a power and energy system.* (Source: [1].)

Although both challenges already entail mitigation options, more research and demonstration is needed to determine how wind and solar power plants, including grid forming capabilities, can become the backbone of future power systems relying on renewable energy sources. For the flexibility needs of wind and solar dominated systems, storage and flexible demand may provide two cost efficient pathways in future. New electrification loads can help for both short-term balancing and for seasonal mismatch of future demand and generation.

Joint articles were published on:

- Grand challenges Grid: listing research needs for wind power plants for grid support services needed in future, led by Imperial College London [2]

- Dynamic Line Rating in Transmission planning, led by LNEG [3]

- Wind energy impact on greenhouse gas reductions towards net zero energy systems, led by OA [4]

Additionally, work on joint publications for publication was ongoing for the Role of sector coupling, storage, and transmission expansion in future energy systems. IEEE PES Magazine issue on inverter based variable generation was prepared by guest editors J.Matevosyan and H.Holttinen, published in March/April 2024; *ieeexplore.ieee.org/document/9246271*

Presentations disseminating the work of Task 25 included:

- TEM Net Zero Studies Dublin Apr 2024: presentations from Denmark, Finland, Ireland, Norway, US, IEA, ENTSO-E as well as modelling challenges by Task 25 OA.

- Recommended Practices Presentations for IEA Wind (H. Holttinen, D. Flynn webinar July 2024); WISO24 Helsinki, ESIG and MIT Boston (H. Holttinen Oct 2024); and Imperial College London (H. Holttinen Feb 2025).

• National events in Sweden (L. Söder, Feb 2024), Denmark (M. Koivisto Nov 2024) and Canada (EMH workshop in conjunction with Task meeting Oct 2024: M. Korpås, A. Estanqueiro, D. Flynn, A. Orths, E. Spyrou, M. Ortega-Vazquez, B. Frew)

Highlights

• Recommended Practices for Wind/PV Integration Studies, Edition 3 was published, including best practices for studying also wind and solar dominated power and energy systems.

• Cross-cutting activities: Energy system integration of renewables is a cross-cutting theme, relevant for many IEA TCPs and other international networks. Task 25 works with Global Power System Transformation Consortium G-PST, IEA, IRENA, and Tasks of other IEA TCPs for solar, hydro, bioenergy and smart grids.

Outcomes and Significance

Energy system impact studies are important for defining targets for wind and other variable sources of renewable energy, but also for defining future decarbonising pathways. Commonly accepted standard methodologies to be applied in system impact studies for wind and solar dominated power and energy systems is a topical research area for years to come and Task 25 has been one of the pioneers to highlight the challenges and solutions. Going forward, there will be solution opportunities from new electrification loads if integrated in a flexible way as well as fully exploiting the capabilities of wind and solar power plants. Power and energy systems dominated by wind and solar pose challenges for system operators both in their planning and operational work. Sharing best practices from wind integration experience, study methods and results has been an important outcome of Task 25.

More recent Tasks of other TCPs can benefit from the knowledge Task 25 has accumulated, and there are more benefits of collaboration between Tasks and TCPs as we go forward in tackling the wider challenge of variable generation in future decarbonised energy systems.

Next Steps

Year 2025 will see the publication of remaining joint articles from Task 25 as well as updated fact sheets and bibliography posted to Task web page. The new Task 25/63 Twenty Fifty Integration of Variable Energy (TWENTY-FIVE) will continue most of Task 25 activities.

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