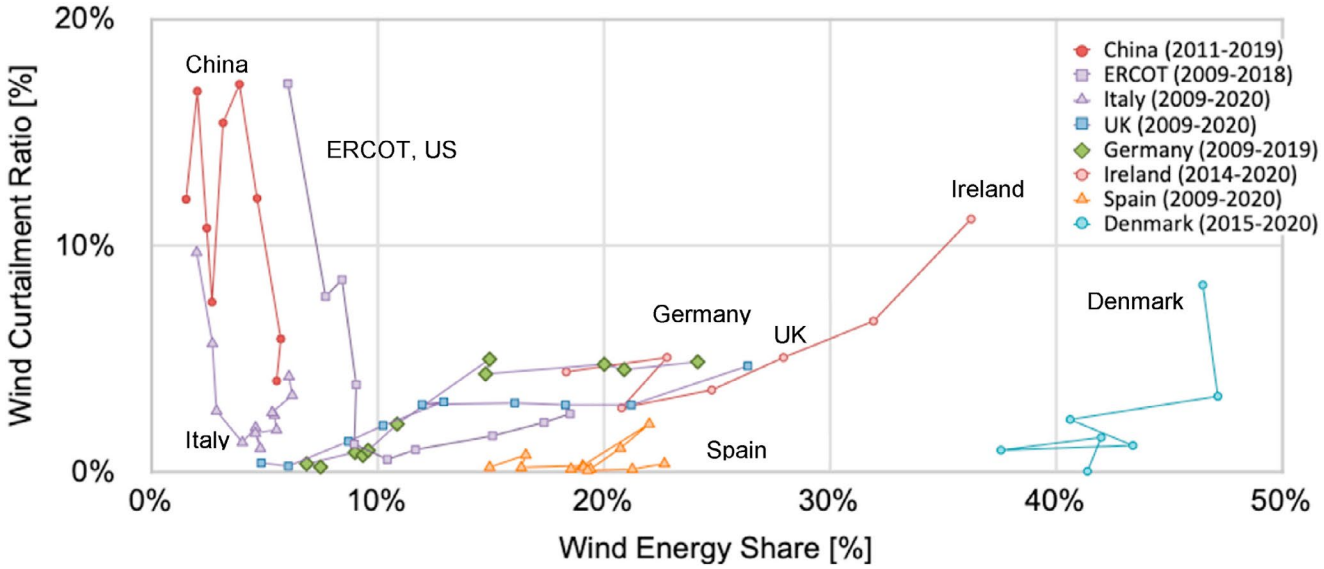

Trends of wind curtailment in some European countries, Texas, and China. Some countries have initially experienced highly curtailed energy, due to a lack of transmission or inflexibilities. It is more common to see the curtailment challenge after a 15-30% share of wind energy [3].

Report 2022

Task 25

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

Author *Hannele Holttinen, Recognis, Finland*

Task 25 aims to develop commonly accepted methodologies which can be applied in system impact studies for wind- and solar-dominated power and energy systems. It assembles best-practice wind integration experience, study methods, and results to member countries and a wider audience through IEA, IRENA, G-PST and ESIG.

Summary

System impact studies are important for defining targets for wind as well as other renewable energy sources. Furthermore, for defining future decarbonisation strategies. The objective of Task 25 is to develop commonly accepted methodologies which can be applied in system impact studies for wind- and solar-dominated power and energy systems. To continue the evolving development of future power and energy systems, international collaboration remains essential to learning from both experience and research within different countries.

In 2021, Task 25 started the final 6th phase of collaboration. The year 2022 began with the last dissemination efforts for a summary report published in October 2021, including

both experience and study results for planning and operating power systems with high shares of wind and solar capacity. The presentations and recordings of this are available on the Task 25 website. Updating Recommended Practices for Wind/PV Integration Studies is the main effort for the Task in 2022 and 2023. In addition, participants have published joint articles, where the 2022 publication surrounded flexibility from electrification, curtailments and market issues.

Task 25 assembles best-practice wind integration experience, study methods, and results to member countries and a wider audience through IEA, IRENA, Global Power System Transformation (G-PST) and ESIG. In addition to international network stakeholders, the main target group of Task 25 are system operators who follow its accomplishments directly and as observers.

Introduction

Task 25 was initiated in 2006 to tackle inconsistencies seen in results for wind integration studies and cost of integration. By analysing the multitude of studies, investigating the power system impact of wind power, most discrepancies could be explained and best practices for system studies were concluded. Since then, a significant amount of knowledge and experience in wind integration has emerged. Meanwhile, targets regarding wind and solar energy shares of demand continue to grow exponentially. Furthermore, the concerns regarding variable generation are shifting from integration costs, to costs of power system inflexibility. Assessing the impacts of this in practice means comparing the costs and reliability of alternative power and energy systems.

Table 1. Countries Participating in Task 25
(new participants for the 2021-24 phase are highlighted in blue)
TSO = Transmission System Operator

	COUNTRY	INSTITUTION(S)
1	**Canada**	NRCan (E.Rebello); University of Victoria (M.McPherson)
2	**China**	SGERI (Wang Yaohua, Liu Jun)
3	**Denmark**	DTU Wind and Energy Systems (Nicolaos Cutululis); TSO Energinet.dk (Antje Orths)
4	**Finland, OA***	Recognis Oy (H.Holttinen); VTT Technical Research Centre of Finland (N.Helistö, J.Kiviluoma)
5	**France**	EdF R&D (E.Neau); TSO RTE (T.Heggarty); MinesTech (G.Kariniotakis)
6	**Germany**	Fraunhofer IEE (J.Dobschinski); FfE (S.vanRoon, A.Guminski)
7	**Ireland**	UCD (D.Flynn); SEAI (J. McCann); Energyreform (J.Dillon)
8	**Italy**	TSO Terna (Enrico Maria Carlini)
9	**Japan**	Kyoto University (Y. Yasuda), CRIEPI (R. Tanabe)
10	**Norway**	NTNU (Magnus Korpås); SINTEF (John Olav Tande, Til Kristian Vrana)
11	**NL**	TUDelft (Simon Watson, Arjen van der Meer); TNO (Germán Morales-España)
12	**Portugal**	LNEG (Ana Estanqueiro), INESC-TEC (Bernardo Silva)
13	**Spain**	University of Castilla La Mancha (Emilio Gomez); Comillas Pontifical University (Andrés Ramos Galán)
14	**Sweden**	KTH (Lennart Söder)
15	**UK**	Imperial College (G. Strbac, M.O'Malley), ORE Catapult (P.Keever)
16	**USA**	NREL (B.Frew, B-M. Hodge), ESIG (J.C. Smith, D.Lew, J.Matevosyan); DoE (J. Fu)
17	**WindEurope**	European Wind Energy Association (Vidushi Dembi, Vasiliki Klonaris)

International collaboration remains essential to learning from both experience and studies in different countries, to continue evolving power and energy systems for the future. Task 25 is in its sixth term in the project span of 2021-2024. The main stakeholders are the system operators joining Task 25 directly and as observers IEA and IRENA, these system operators are frequent observers of Task 25 meetings.

Task 25 is active in inter-TCP collaboration, therefore solar integration (PVPS TCO 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).

Progress and Achievements

Through Task meetings, an international forum has been established for member countries, as well as their Transmission System Operators (TSOs). This has the purpose of exchanging knowledge and experiences with electricity system operations where large amounts of wind and solar energy are involved.

The meeting in 2022 was a hybrid to include both in-person and online participation. Virtual participation enables greater collaboration with member countries, in addition to reaching more stakeholders, as well as other TCP observers. TSOs from Denmark, France, Ireland, Italy, and the UK joined meetings in 2022. The spring meeting was hosted by VTT in Espoo, Finland, and the Autumn meeting by Imperial College in London, which was held in conjunction with a Global Power System Transformation Consortium (G-PST) research workshop.

The year 2022 started with the last dissemination webinars for the summary report, which highlighted the main results of national case studies, as well as experience in operating and planning power systems with high shares of wind and solar energy [1]. Joint articles were published for;

- How flexibility from the electrification is supporting a 100% Sustainable Energy System, in IEEE Power and Energy Magazine led by VTT [2],
- Updating curtailment versus energy share maps, in Renewable and Sustainable Energy Reviews, led by Kyoto University [3],
- Market design issues, presentation and paper in EEM22 proceedings led by Sintef [4].

Additionally, work on joint publications for 2023 was ongoing for Grand Challenges Grid, Dynamic Line Rating in Transmission planning, Intra-hour balancing, and Role of sector coupling, storage, and transmission expansion in future energy systems.

Task 25 highlights the evolving best practices on system impact studies for the feasibility of wind- and solar-dominated power systems. Recommended Practices RP16 is currently being updated to Edition 3, which includes recommendations for studies concerning close to 100% renewable systems. The main challenges include power system stability, due to the inverter-based, non-synchronous grid interface, and balancing, which is attributed to varying resources. Mitigation options for both challenges have already been proposed, however, research and demonstration is necessary to determine how wind and solar power plants, including grid-forming capabilities, can become the backbone of future power systems. To compensate for the flexibility needs of 100% renewables systems, storage and flexible demand may provide two cost-efficient pathways for the future. This is dependent on how far cost reductions of storage technologies will go and how much new electrification loads can help, for both short-term balancing, as well as seasonal mismatch of future demand and generation [5].

Presentations disseminating the work of Task 25 included:

- Summary report ESIG webinar January 2022 (H. Holttinen). Of the 220 attendees, more than 50% were from the US, yet also represented a global coverage with more than 50 utility/system operator participants.
- Summary report Leonardo webinar March 2022 (H. Holttinen). Registrations: 377, unique live participants: 183, who were mostly European.
- EERA ESI System cost workshop presentations 19-20 September 2022 (H. Holttinen, L. Söder, J. Kiviluoma).
- IEA/ISGAN workshop Paris October 3, Flexibility for resilience (H. Holttinen).
- 3 presentations for a national audience in Norway. Norway Energy Commission, NVE energidagene and HydroConnect workshop (M. Korpås).

Highlights

Task 25 has formed links with additional System Operator networks, namely Global Power System Transformation Consortium G-PST collaboration, in the current phase. Task 25 was involved in their Inaugural Research Agenda publication and contributed to their research repository, as well as helped organise a joint workshop on future research projects.

IEA and IRENA have joined Task 25 meetings to present their ongoing work, while Task 25 has written reviews of their publications regarding system integration.

Collaboration with IEA PVPS Task 14 resulted in an update of the Recommended Practices for Wind/PV Integration Studies (RP 16 Ed 2) in 2018 [2], which was also published as an IEA TCP PVPS report in 2019.

In regard to the current update of Recommended Practices, including challenges towards 100% renewables, Task 14 is again contributing to the distribution system and solar integration issues.

In 2022, Task 25 had other IEA TCP contacts regarding the value of flexibility of the different technologies (Hydro, Biomass), as well as transmission and resilience challenges (ISGAN).

More recent Tasks of other TCPs can benefit from the knowledge Task 25 has accumulated, meanwhile the benefits of collaboration between Tasks and TCPs continue to grow as we go forward and tackle the wider challenge of variable generation in future decarbonised energy systems. Pursuing these challenges together, potentially with a joint Task of several TCPs poses a potential opportunity.

Outcomes and Significance

System impact studies are important for defining targets for wind and other variable renewable energy. Furthermore, for defining future decarbonisation opportunities. Task 25 is dedicated to developing commonly accepted standard methodologies which can be applied in system impact studies for wind- and solar-dominated power and energy systems.

An example which highlights the challenges that wind and solar pose to power systems is depicted in the opening graph (Figure 1.). It illustrates how large shares of wind (and solar) energy are unable to be absorbed in power system operation, resulting in curtailments of wind energy.

Task 25 brings best practice wind integration experience, study methods, and results to member countries. Technically, it is possible to integrate significant amounts of wind and solar capacity into power systems, especially when new electrification loads are integrated in a flexible manner and the capabilities of wind and solar power plants are fully exploited.
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Next Steps

The coming year of 2023 will include the publication of several Task 25 joint articles, such as the Grand Challenge Grid to Wind Energy Science. Additional journal article topics currently in progress are the intra-hour balancing challenge, wind energy capabilities for Ancillary Services, and Dynamic Line Rating benefits for wind integration.

Recommended Practices Update is aiming for the report to be ready for review by the end of 2023.

So far, the two following meetings for 2023 have been organised: May 2023 in Kyoto, Japan, hosted by Kyoto University and TEPCO, and the Autumn meeting is intended to be hosted in either Rome or Kassel.

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Task Contact

Contacts:
Hannele Holttinen,
Recognis, Finland.
Niina Helistö,
Technical Research Centre of Finland (VTT), Finland.

Emails:
hannele.holttinen@recognis.fi
niina.helisto@vtt.fi

Website:
https://iea-wind.org/task25/