第14回
IEA Wind セミナー

2025年9月24日

Task 63:
2050年に向けた 変動性エネルギーの統合

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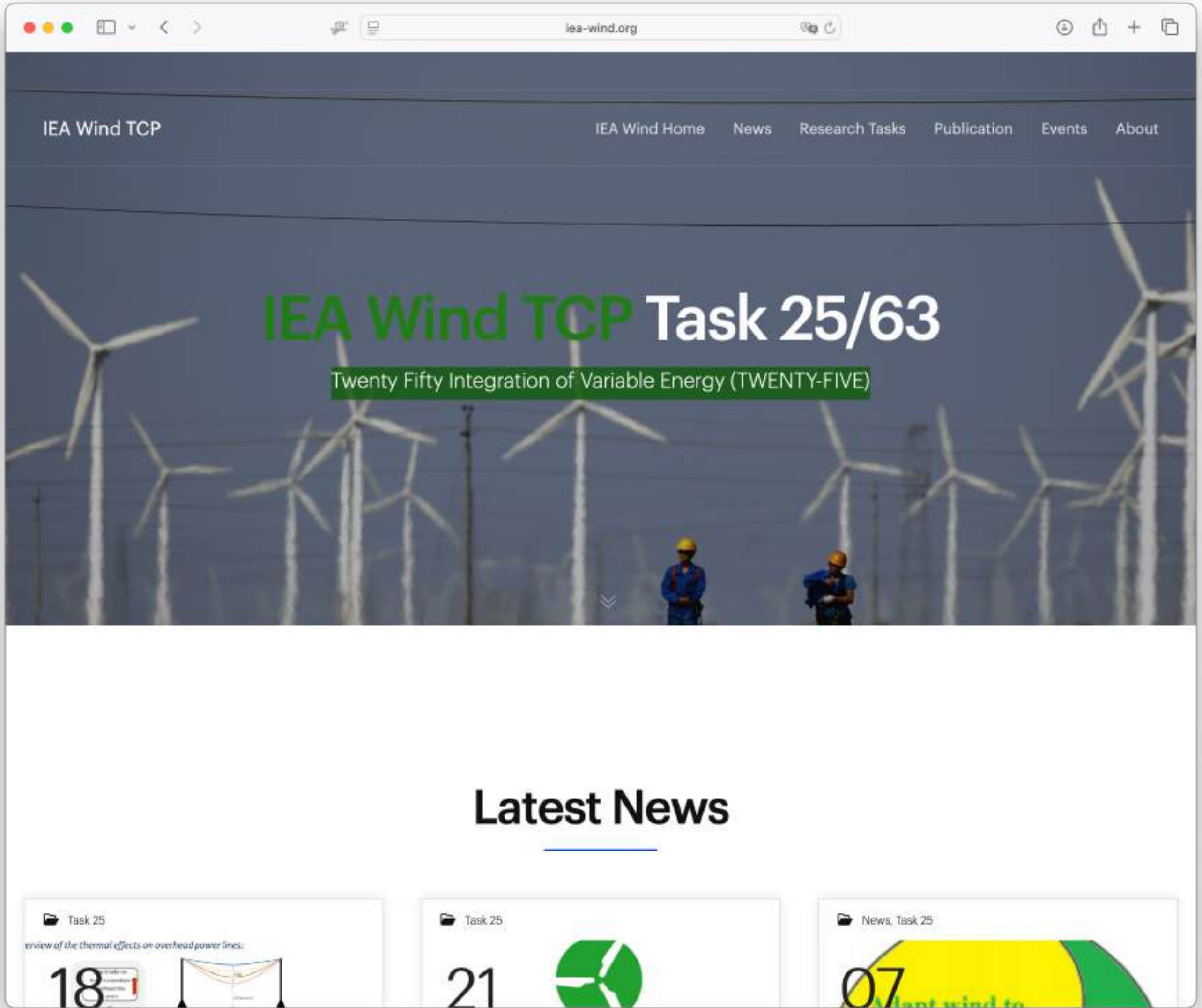
Task 63 の紹介

- 名称
  - Twenty Fifty Integration of Variable Energy (TWENTY-FIVE)
  - 2050 年に向けた変動性エネルギーの統合

- 目的
  - エネルギーシステムへの変動性再生可能エネルギーの大量導入を促進する最も経済的に実現可能な方法に関する情報の提供
  - 風力発電が大量導入された電力系統の運用に関する知識と経験の情報交換
  - 旧Task25の後継委員会

Task 25/63 のウェブサイト



https://iea-wind.org/task25-63/

Task25のこれまでの活動経緯

- 第1期 (2006～2008年, 11ヶ国+1団体(EWEA))
  - 第１期報告書(2009) → 日本語訳(2012)
- 第2期 (2009～2011年, 14ヶ国+1) ← 日本参加
  - 第2期報告書(2012)
- 第3期 (2012～2014年, 15ヶ国+1)
  - 第3期報告書(2015) → 日本語訳(2020), RP16(2013)
- 第4期 (2015～2017年, 16ヶ国+1)
  - 第4期報告書(2018)
  - RP16(2018)(PVPS Task14と共同)→ 日本語訳(2023)
- 第5期 (2017～2020年, 18ヶ国+1)
  - Fact Sheet 2020年版 → 日本語訳(2020)
  - 第5期報告書(2021) → 日本語訳(2023)
- 第6期 (2021年～2024, 15ヶ国+2)
  - RP16(2024) 3rd Edition (PVPS Task14と共同)
  - Fact Sheet 2025年版

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Task25/63の構成

女性率も高い
(ジェンダーバランス)

- 構成メンバー
  - TSOなど実務者も多い
    - Hydro Québec(CA)
    - Energinet.dk (DK)
    - TenneT (DE)
    - RTE (FR)
    - Terna (IT)
- 日本委員
  - 安田 陽 (ISEP/九大) 2010年～
  - 田辺隆也 (電力中央研究所) 2014年～

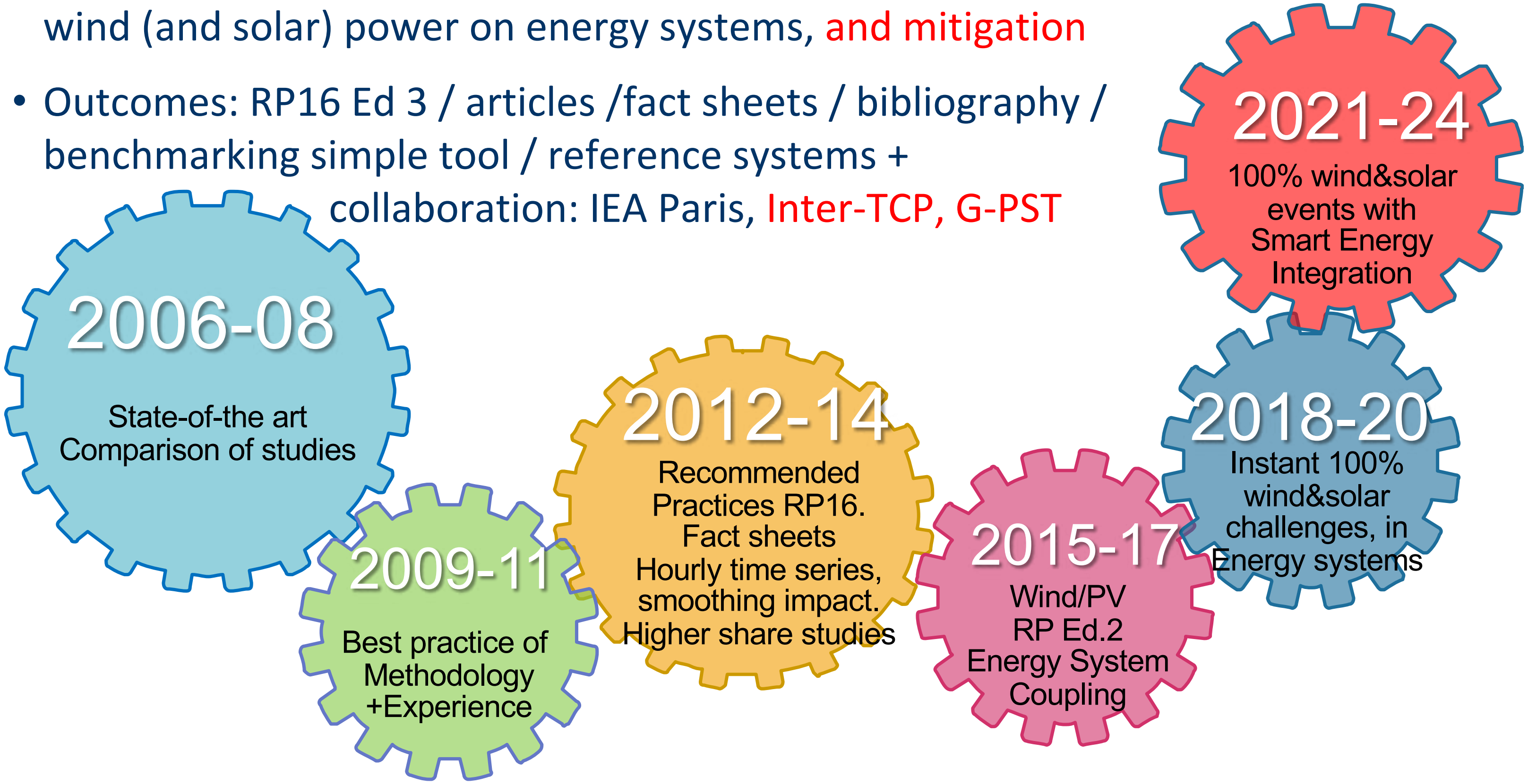
Country	Organisation
	HydroQuebec
	DTU TSO Energinet
	Recognis Oy VTT
	EdF R&D TSO RTE MINES ParisTech
	Fraunhofer IEE The Research Center for Energy Economics (FfE)
	University College Dublin (UCD), School of Electrical & Electronic Engineering
	TSO Terna
	Kyoto University Central Research Institute of Electric Power Industry (CRIEPI)

	Delft University of Technology (TUDelft) TNO
	NTNU SINTEF Energy Research
	Laboratório Nacional de Energia e Geologia (LNEG) Institute for Systems and Computer Engineering, Technology and Science (INESC TEC)
	University of Castilla-La Mancha (UCLM) Comillas Pontifical University
	Royal Institute of Technology (KTH)
	Imperial College
	National Renewable Energy Laboratory (NREL) Energy System Integration Group (ESIG, formerly UVIG) U.S. Department of Energy (DOE)

旧Task25の活動経緯

Task Objectives & Expected Results

- Objectives: recommend methodology to assess the impact of wind (and solar) power on energy systems, and mitigation
- Outcomes: RP16 Ed 3 / articles /fact sheets / bibliography / benchmarking simple tool / reference systems + collaboration: IEA Paris, Inter-TCP, G-PST



Task25/63のワークプラン

- **WP1: Planning Topics** 系統計画
  - Transmission Planning
  - Generation capacity expansion and security of supply
  - Energy System Integration
- **WP2: Balancing Topics** 需給調整 (含む柔軟性)
  - Balancing the system
  - Need for flexibility and options to provide flexibility
  - Smart sector integration
- **WP3: Stability Topics** 安定度 (含む慣性問題)
  - Operation and stability of low-inertia RES power systems
  - Design and operational requirements
  - Reliability services
- **WP4: Market Topics** 電力市場
  - Ancillary Service marts to energy markets and capacity market
  - New market products, such as flexible ramping products.

2024～25年度の活動

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- 2024年春季
  - 開催都市: Dublin, Ireland 🇮🇪
  - ホスト: SEAI (アイルランド持続可能エネルギー庁)
  - 2024年4月10～12日
  - 参加者: 約40名
  - TEM#113 (Net Zero Electricity System)と併催
  - Task25の後継委員会の提案

2024～25年度の活動

- 2024年秋季
  - 開催都市: Victoria, Canada 🇨🇦
  - 2024年10月28日～30日
  - ホスト: University of Victoria
  - 参加者: 約20名
  - 併催イベント: IESVic (Institute for Integrated Energy Systems) Workshop
  - Task25として最後の会合

2024～25年度の活動

- 2025年春季
  - 開催都市: Oslo, Norway 🇳🇴
  - ホスト: SINTF (ノルウェー産業技術研究所)
  - 2025年5月12～14日
  - 参加者: 約30名
  - 併催イベント: Energy modelling workshop
  - Task63として最初の会合

第5期最終報告書 (目次より)

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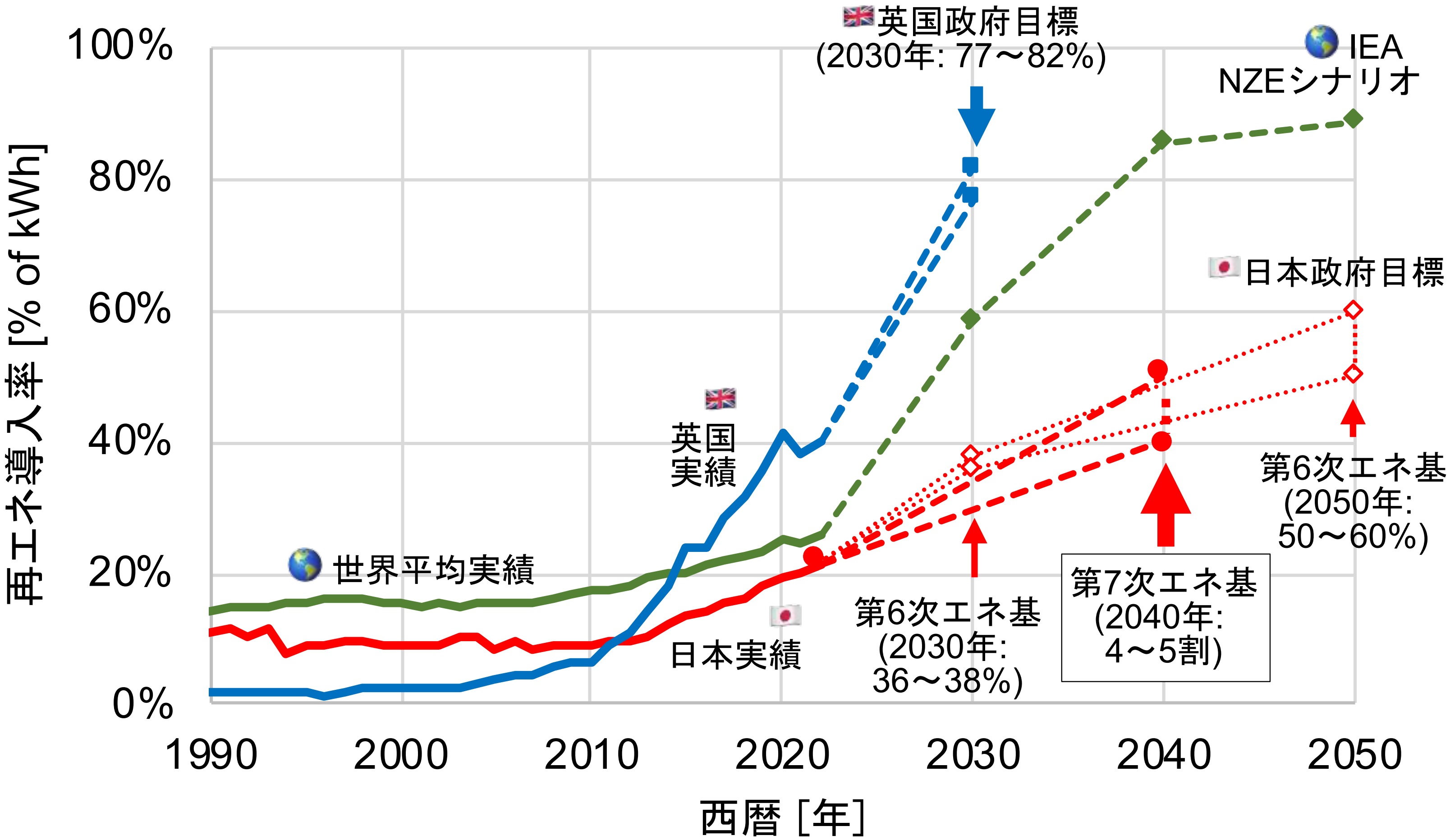
- 1. はじめに
- 2. 電力システム全体にわたる 風力・太陽光発電の変動性と不確実性
- 3. 送電計画
- 4. 長期的供給信頼度と電力の安定供給の確保
- 5. 短期的システム信頼度の確保
- 6. 運用中の風力発電の価値を最大化する
- 7. 現状を打破する：再生可能エネルギー100%シェアに向けて

再生可能エネルギー100%に近いシステム運用のための課題

- 従来型電源がなくても電力システムの強度を維持する、つまりシステム安定度を確保するための技術的なソリューションが、いくつかの場合で存在することは、一般的な科学的コンセンサスとなっている。分散型太陽光発電の比率が大きい電力システムの場合、特定の困難が予想される。分散型太陽光発電が配電網やセキュリティに与える影響について、さらなる評価が必要である。(p.116)
- 風力や太陽光などの変動性電源が中心のシステムでも、デマンドレスポンス、大規模エネルギー貯蔵、ピーク電源、整備された送電網や連系線などの柔軟性があれば、系統アデカシー(電力システムがつねに負荷に対処する能力)を確保することができる。これらの柔軟性電源の成熟度、利用可能性、コストについて検討する必要がある。(p.117)

(出典) IEA Wind TCP Task25: 変動性電源大量導入時のエネルギーシステムの設計と運用 最終報告書, NEDO (2023)
https://www.nedo.go.jp/content/100959887.pdf

【参考】再エネ将来目標日英比較



(data source) IEA: Energy Statistics Data Browser
https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser
IEA: World Energy Outlook 2024, Oct. 2024
https://www.iea.org/reports/world-energy-outlook-2024
資源エネルギー庁: エネルギー基本計画, 2021年10月22日
https://www.meti.go.jp/press/2021/10/20211022005/20211022005-1.pdf
資源エネルギー庁: エネルギー基本計画, 2025年2月18日
https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2024/067/067_005.pdf
UK Government: Clean Power 2030 Action Plan: A new era of clean electricity, 13 December 2024
https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/20250218_01.pdf

Fact Sheet 2025年版 (出力抑制)

WIND AND SOLAR ENERGY CURTAILMENT

Curtailment of wind and solar sometimes occurs in surplus periods when electricity demand is low or when network capacity is congested. Curtailing wind and solar is not necessarily a bad thing as it may enable larger shares of renewables through making them flexible. Although a moderate amount of curtailed energy can be tolerated, huge amounts of wasted energy from near-zero operating cost renewable energy sources would be inefficient and unprofitable.

Is wind and solar curtailment required?

If curtailment of wind and solar would be strictly prohibited in a power system, only limited amounts of wind and solar could be installed and connected to the system. Not everyone needs electricity exactly when the wind blows and the sun shines, so sometimes the power generated from wind and solar is excessive. Zero curtailment may represent a sub-optimal solution.

Figure 1 illustrates the duration curve (energy values sorted in descending order) of net load, or residual load, that is the difference between total demand and total output from wind and solar. Surplus situations occur when the net load turns negative, meaning wind and solar output exceeds demand. At higher shares of renewables, such periods will become more common, and the amount of surplus energy tends to increase with the installed capacity of wind and solar. Surplus energy can be caused by local constraints, leading to curtailments at some parts of the system before system-wide limits. Building transmission helps export the supply to high-demand areas.

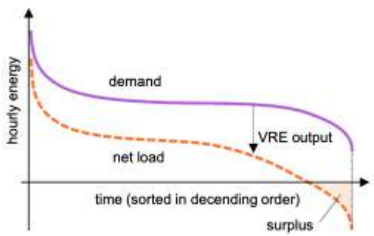


Figure 1. Conceptual illustration of surplus energy in duration curve of net load with large amounts of VRE (wind + solar).

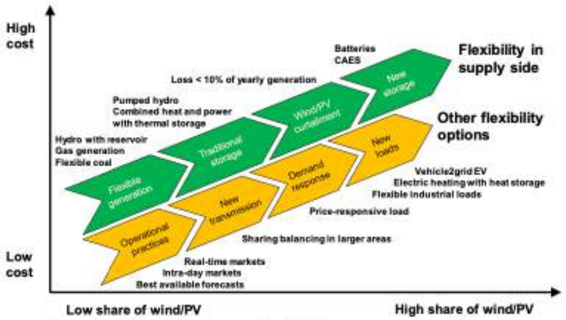


Figure 2. Methods to increase flexibility in power systems. (The relative order of options is illustrative only).

Options to reduce surplus energy are: output reduction of conventional power plants, export to other areas, demand side management, and energy storage. If these options are costly or have been exhausted, curtailment could be appropriate to manage the surplus energy of wind and solar. Large amounts of curtailment, however, show lack of system flexibility or appropriate market design.

Wind and solar operators can provide upward reserves when a part of the available energy from wind or solar resource is curtailed, where the lost energy provides the basis for the provision of these valuable system services. Curtailment is a way for wind and solar to provide flexibility (Figure 2).

Evaluation and comparison of curtailment

The level of curtailment depends on system being analysed. It also varies depending upon the time of year, such as by hour, day, week and month. Hence, comparisons of annual curtailments in different systems are more insightful than those made based on an arbitrary period.

Figures 3 and 4 illustrate wind and solar curtailment, respectively, in selected countries or areas in the form of C-E maps (correlation maps between energy share of wind/solar/wind+solar and annual curtailment ratio). Figure 5 illustrates total wind and solar curtailment.

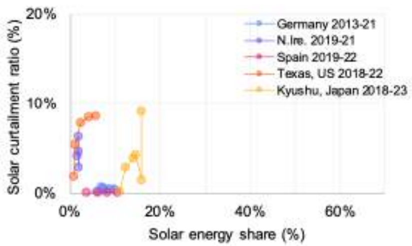


Figure 3. C-E map of solar in selected countries/areas. (Source: adapted from Yasuda et al., 2023).

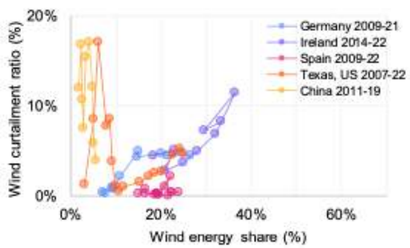


Figure 4. C-E map of wind in selected countries/areas. (Source: adapted from Yasuda et al., 2023).

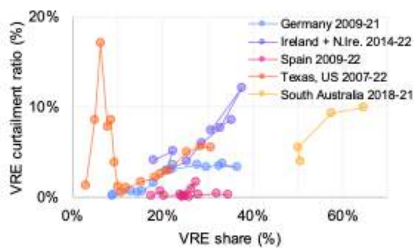


Figure 5. C-E map of VRE (wind + solar) in selected countries/areas. (Source: adapted from Yasuda et al., 2023).

The three graphs show that there are several countries/areas where the curtailment ratio is large, despite the small energy share. The sharp decline in some countries/areas, such as China and Texas, is likely to be due to the rapid development of transmission lines following large curtailments, which means that the curtailment problem could be quickly resolved through appropriate measures. The Irish curtailments in Figure 4, where large wind share is managed in a small synchronous zone, gives a reference on how curtailments develop as wind share increases in the future.

Remark on Figures 3–5: Note that curtailment in some of the countries, such as Australia and US, may include "economic dispatch" that is voluntary market behaviour, which should be distinguished from the curtailment that is forced by transmission system operators. Note also that evaluating the C-E map by the total volume of wind and solar curtailment could be misleading as it may result in an underestimation/overestimation of the levels of individual wind/solar curtailment in some countries/areas where the share of one of the two sources is very large and the other very small.

Associated publications

- Holttinen, H. et al. (2021). **Design and operation of energy systems with large amounts of variable generation**. Final summary report, IEA WIND TCP Task 25. https://doi.org/10.32040/2242-122X.2021.T396
- Yasuda, Y. et al. (2022). **C-E (curtailment – Energy share) map: An objective and quantitative measure to evaluate wind and solar curtailment**. Renewable and Sustainable Energy Reviews, 160 (2022) 112212. https://doi.org/10.1016/j.rser.2022.112212
- Yasuda, Y. et al. (2023). **Latest wind and solar curtailment information: statistics and future estimations in various countries/areas**. 22nd Wind and Solar Energy Workshop. https://iea-wind.org/task25/t25-publications/

More information

This Fact Sheet draws from the work of IEA Wind TCP Task 25, a research collaboration among 17 countries. The vision in the start of this network was to provide information to facilitate the highest economically feasible wind energy share within electricity power systems worldwide. IEA Wind TCP Task 25 has since broadened its focus to analyze and further develop the methodology to assess the impact of wind and solar power on power and energy systems.

See our website at

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

See also other fact sheets

Flexibility for Power Systems
Balancing Power Systems with Large Shares of Wind and Solar Energy
Storage for Power Systems
Wind and Solar Integration Issues

Fact Sheet 2025年版 (柔軟性)

FLEXIBILITY FOR POWER SYSTEMS

Flexibility is the ability of a power system to manage variability of demand and generation. Flexibility includes power regulation and operational reserves, which have historically depended on thermal power plants. On top of dispatchable power generators, there are new sources of flexibility increasingly used, like energy storage, interconnectors and demand side management. The optimal combination of flexibility is a key issue for grid operation under large amounts of wind and solar.

What is flexibility?

Traditionally, intra-hour, hourly, daily, weekly, seasonal, and inter-annual variations in demand have been mainly managed by conventional power plants.

The ability and commitment of a power plant to regulate its power output has been called regulating power, balancing power or reserve, and various types of these products with different time scales are prepared, so that they can be activated in seconds, minutes, or hours.

Today, a broader concept of flexibility is increasingly applied by grid operators to accommodate larger amounts of wind and solar.

The term "flexibility" is simply defined as "the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales" (IEA 2018).

Who can provide flexibility?

Flexibility can be provided from many grid elements, by larger or (aggregated) smaller power plants, storage systems, and demand side resources, depending on the time scale (Figure 1).

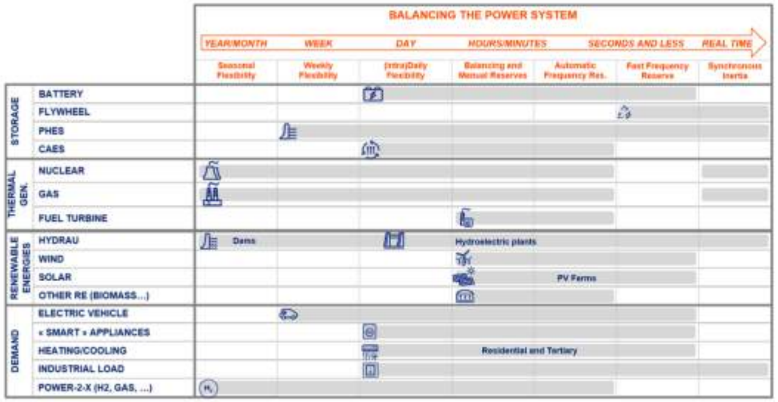


Figure 1. *Flexibility solutions at various time scales. (Source: EDF).*

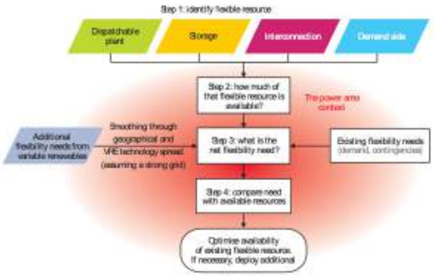


***Figure 2.** Flexibility Assessment Method proposed by IEA. (Source: IEA, 2011).*

Flexibility sources can be divided into 4 types (Figure 2):

- **Dispatchable plant:** Hydropower plant with reservoir, bio-fuelled combined heat and power plant, gas-fired power plant, etc. A part of wind and solar can also be considered dispatchable.
- **Storage:** Hot water storage, pumped hydro storage, flywheel, battery energy storage system, etc.
- **Interconnection:** Sharing flexibility resources via interconnectors will mutually enhance flexibility in both areas. HVDC (High Voltage Direct Current) links can also provide flexibility by themselves.
- **Demand side:** Autonomous or remote control of demand side equipment can provide flexibility. Industrial processes also have significant potential for flexibility provision.

Flexibility strongly relates to the concept of sector coupling. Flexibility can be provided from the heating sector (hot-water storage and heat pumps), the transport sector (electric vehicle charging), and the industrial sector (new electric loads combined with storage buffers as well as power-to-X solutions like hydrogen derivatives).

How can the flexibility potential be assessed?

Flexibility assessment tools have been proposed by several researchers and international organisations. A simple, easy-to-understand and at-a-glance tool is Flexibility Chart developed by IEA Wind Task 25 (Yasuda et al., 2023).

The standard Flexibility Chart contains five axes that represent the proportion of selected flexibility sources (interconnector, combined heat and power, gas turbine, pumped hydro storage and reservoir hydro) relative to the peak demand in the given country or area. As these statistical data are easily available in many countries, the tool can be used even by non-experts. A further sixth axis of battery can be added if reliable statistical data is available.

Figure 3 shows an example of the Flexibility Chart, where the potential of flexibility resources in Germany is visually illustrated. Although it is often thought that Germany can accommodate renewables because of rich interconnection capacity, the Flexibility Chart shows that combined heat and power capacity can contribute more flexibility to a high share of VRE.

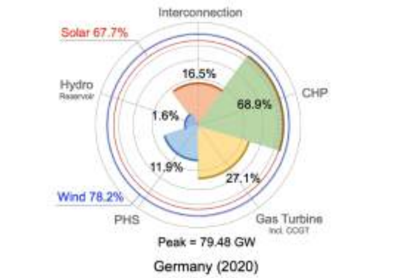


***Figure 3.** An example of flexibility chart: German flexibility resources in 2020. (Source: Yasuda et al., 2023).*

An example of a more detailed flexibility assessment tool is IRENA FlexTool (IRENA 2018).

Associated publications

- Holttinen, H. et al. (2021). **Design and operation of energy systems with large amounts of variable generation**. Final summary report, IEA WIND TCP Task 25. https://doi.org/10.32040/2242-122X.2021.T396
- IEA (2018). **Status of Power System Transformation 2018**. https://www.iea.org/reports/status-of-power-system-transformation-2018
- IEA (2011). **Harnessing Variable Renewables**. https://www.iea.org/reports/harnessing-variable-renewables
- IRENA (2018). **Power System Flexibility for the Energy Transition, Part 1: Overview for Policy Makers**. https://www.irena.org/publications/2018/Nov/Power-system-flexibility-for-the-energy-transition
- Yasuda, Y. et al. (2023) **Flexibility chart 2.0: An accessible visual tool to evaluate flexibility resources in power systems**. Renewable and Sustainable Energy Reviews, 174 (2023) 113116. https://doi.org/10.1016/j.rser.2022.113116

More information

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See our website at

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

See also other fact sheets

Balancing Power Systems with Large Shares of Wind and Solar Energy
Storage for Power Systems
Flexibility Through Electrification
Impact of Wind and Solar on Transmission Upgrade Needs
Wind and Solar Integration Issues

日本からの貢献

- Task25有志による共同論文（安田）
  - 出力抑制国際比較
    - Phase 4 Summary Report (2018)に掲載
    - Renewable and Sustainable Energy Review に掲載 (Volume 160, May 2022, 112212)
  - 柔軟性チャート
    - Renewable and Sustainable Energy Review に掲載 (Volume 174, March 2023, 113116)

C-E マップ最新版

iea wind

Solar

当日スライドにて投影

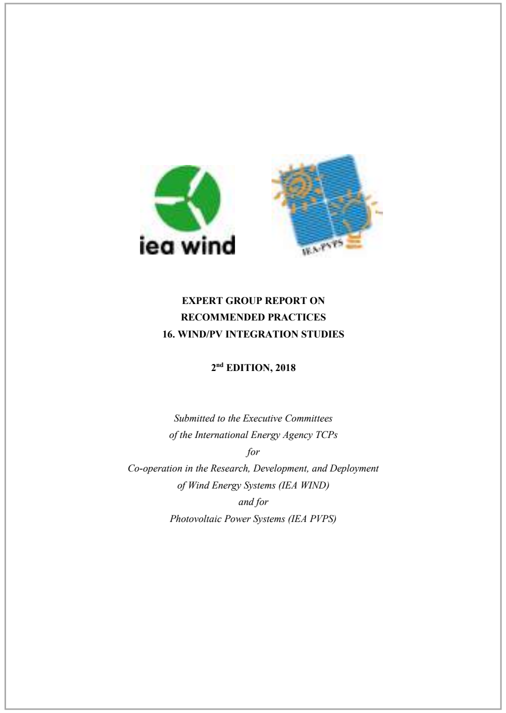
Wind

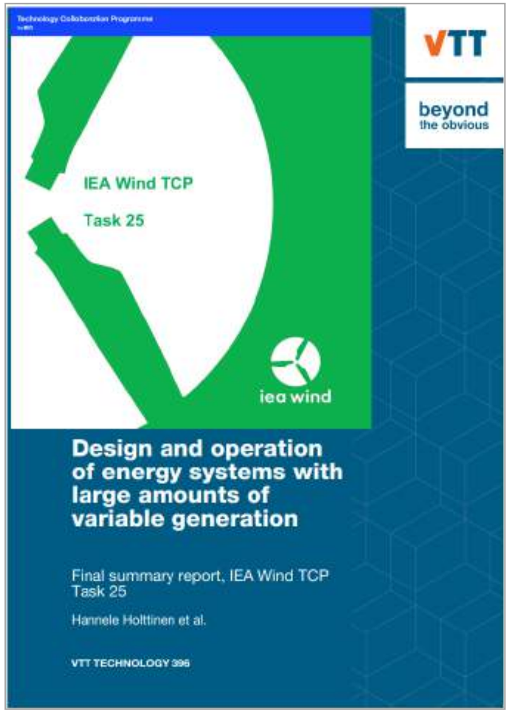
当日スライドにて投影

(source) Y. Yasuda et al.: Latest Wind and Solar Curtailment Information: statistics and future estimations in various countries/areas, 22nd Wind & Solar Integration Workshop, WISO23-143 (Sep. 2023) に最新データを加筆して修正

Task25成果物の翻訳

- RP16 (2018)(PVPS Task14と共同)
- 第5期報告書 (2021)
  - https://www.nedo.go.jp/library/ZZFF_100047.html
- ファクトシート (2020年版)
  - https://www.nedo.go.jp/library/ZZFF_100033.html





まとめと今後の方針

毎年同じこと
言ってますが…

- 再生可能エネルギーの系統連系（エネルギー統合）に関する情報や概念は、依然として日本と世界で乖離
- Task25/63から得られる情報は非常に貴重
- 世界☞日本: Task25/63の情報の普及啓発
  - 報告書の翻訳
- 日本☞世界: 日本からTask25/63への貢献
  - 国際共同論文
  - NEDOプロ成果などの発表

第14回
IEA Wind
セミナー

Task 63:
2050年に向けた
変動性エネルギーの統合

ご清聴有り難うございました。