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The Role of Small Modular Reactors in the Energy Transition

Converging Energy Technologies – CET2024

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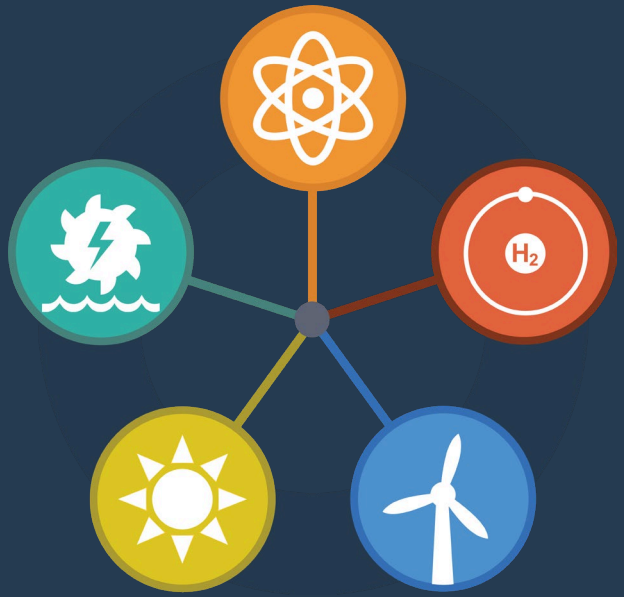
NERES research project at NTNU

«Nuclear Energy's role in a Renewable Energy System (NERES)»



Funding:	Internally (NTNU)
Timeframe:	March 2023 – Dec 2025
Homepage:	https://www.ntnu.no/iel/neres
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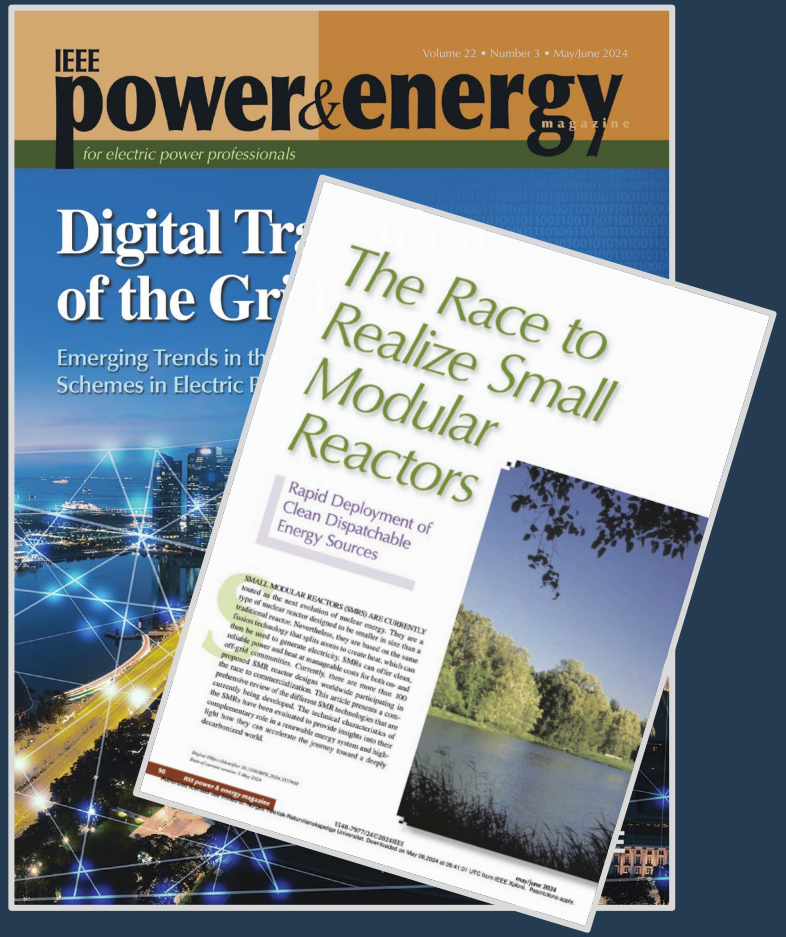
Agenda

1. Current status
2. How SMRs could be the backbone for renewables
3. The role of nuclear energy in the European power system
4. Conclusion and key takeaways

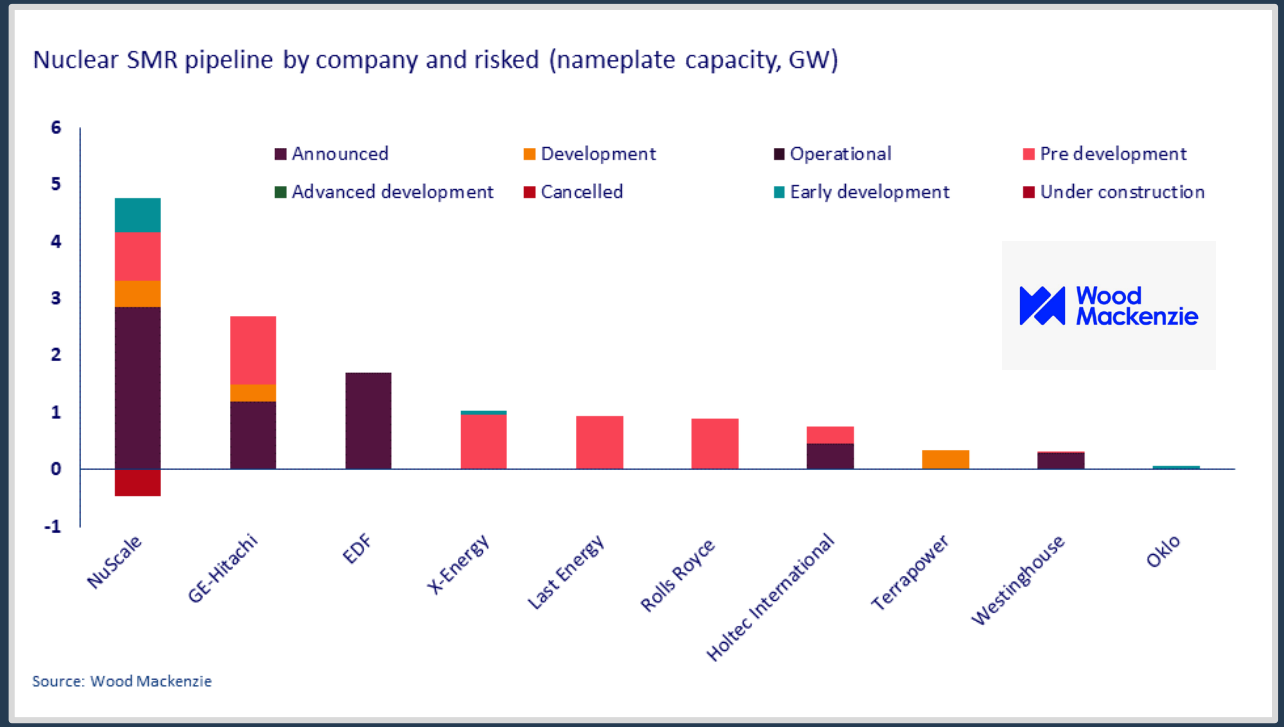


1. CURRENT STATUS

SMR pipeline 2024

Wood Mackenzie:

"We expect first-of-a-kind SMRs to cost around $180/MWh, falling by 40% to $100/MWh by 2030, driven by innovation and scaling up."

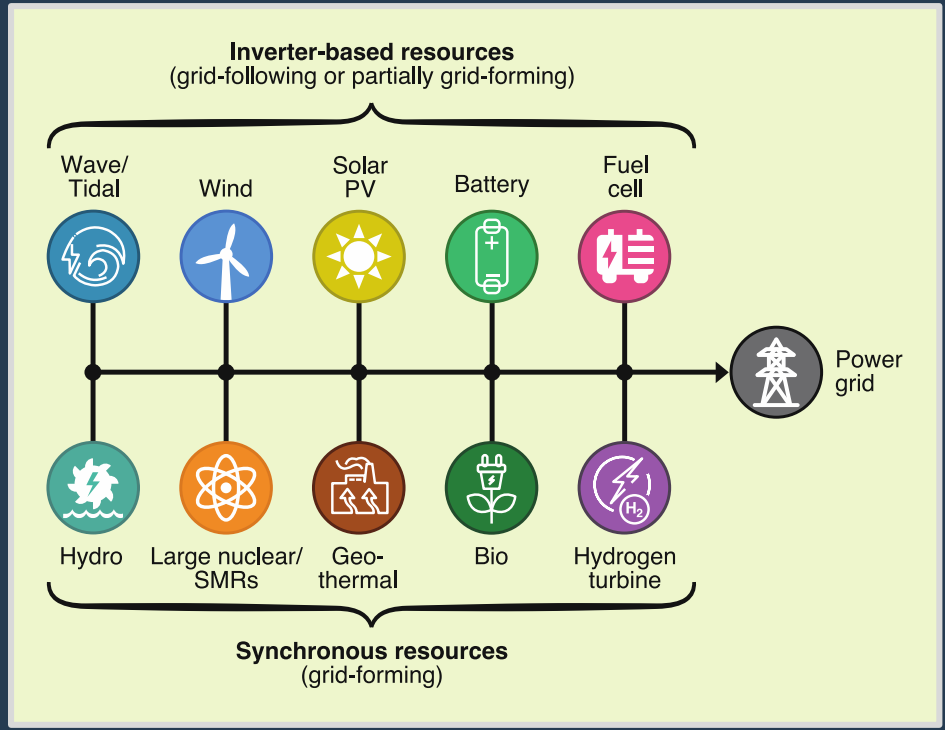


S. Flowers and D. Brown, "Nuclear's massive net zero growth opportunity," *Wood Mackenzie*, March 2024.

2. HOW SMRS COULD BE THE BACKBONE FOR RENEWABLES

Future fossil-free power grid composition

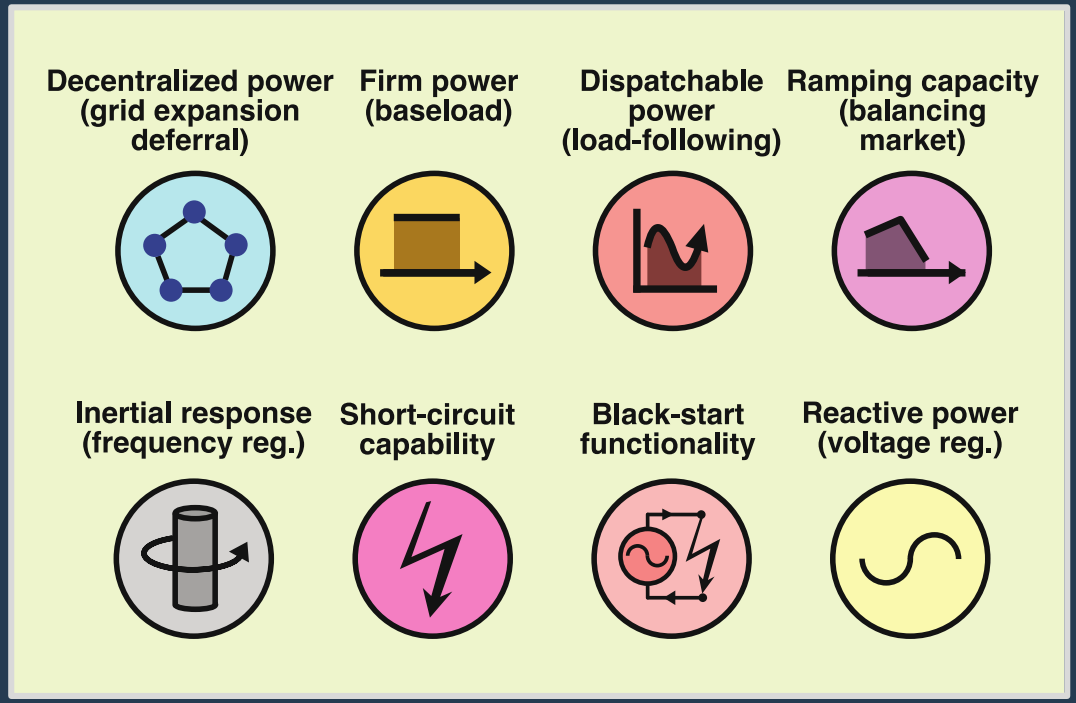
Less firm synchronous resources in the future power system. The only exceptions are nuclear and geothermal.



Source: J. K. Nøland, *et al.*, "Running Renewable-Rich Power Grids," *IEEE Electrification Magazine*, December 2024.

System-bearing services from SMRs

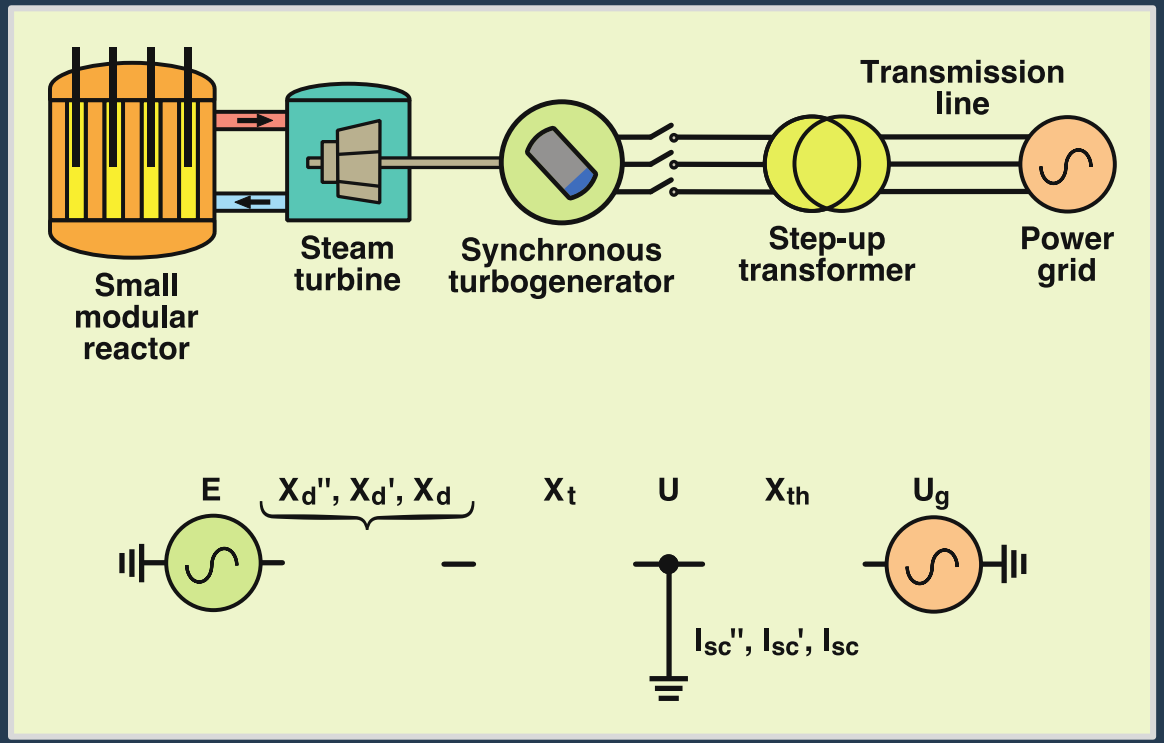
System-bearing services that can be provided to the future power grid by small modular reactors.



Source: J. K. Nøland, *et al.*, "Running Renewable-Rich Power Grids," *IEEE Electrification Magazine*, December 2024.

Grid equivalent of an SMR during faults

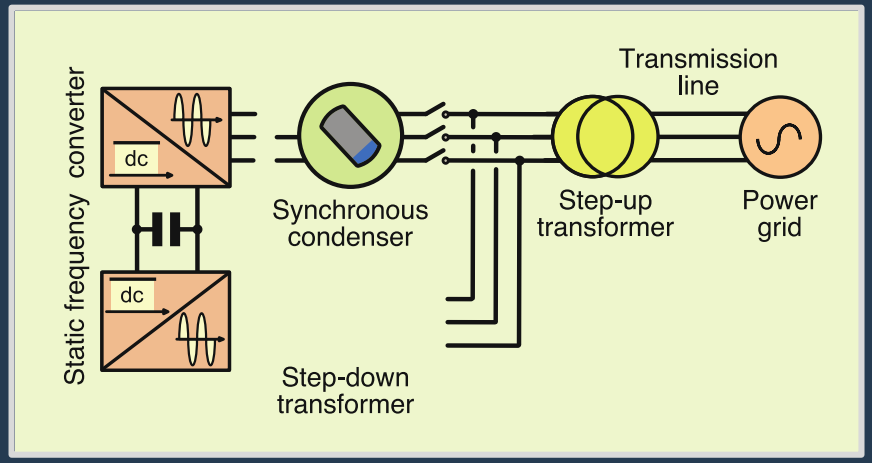
Three-phase diagram of an SMR connected to a power grid and single-line diagram during a grid fault.

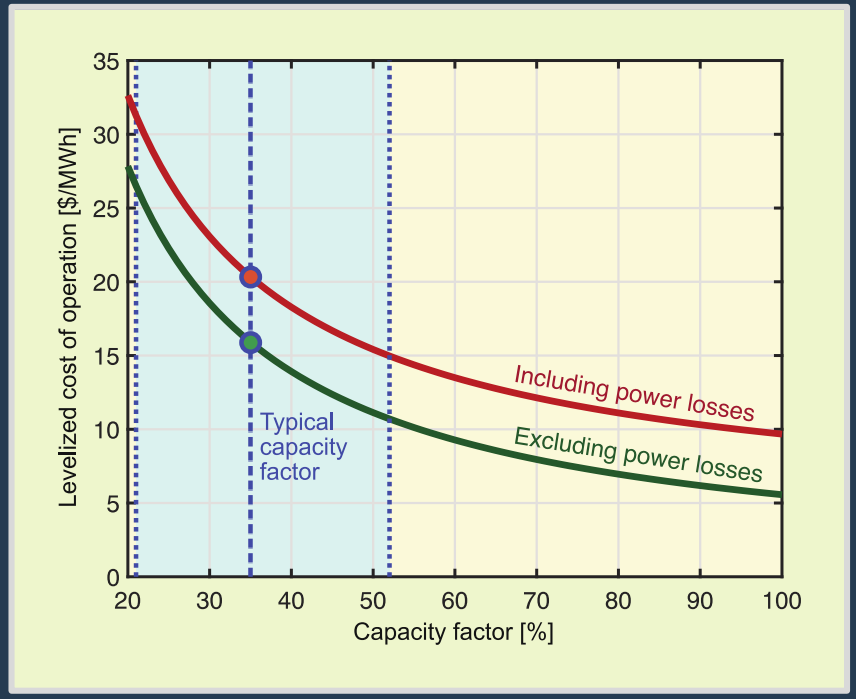


Source: J. K. Nøland, *et al.*, “Running Renewable-Rich Power Grids,” *IEEE Electrification Magazine*, December 2024.

Alternative solution: SynCons

Typical capacity factors of synchronous condensers (SynCons) are 35 %, adding extra $20/MWh in system cost to help integrate renewables.

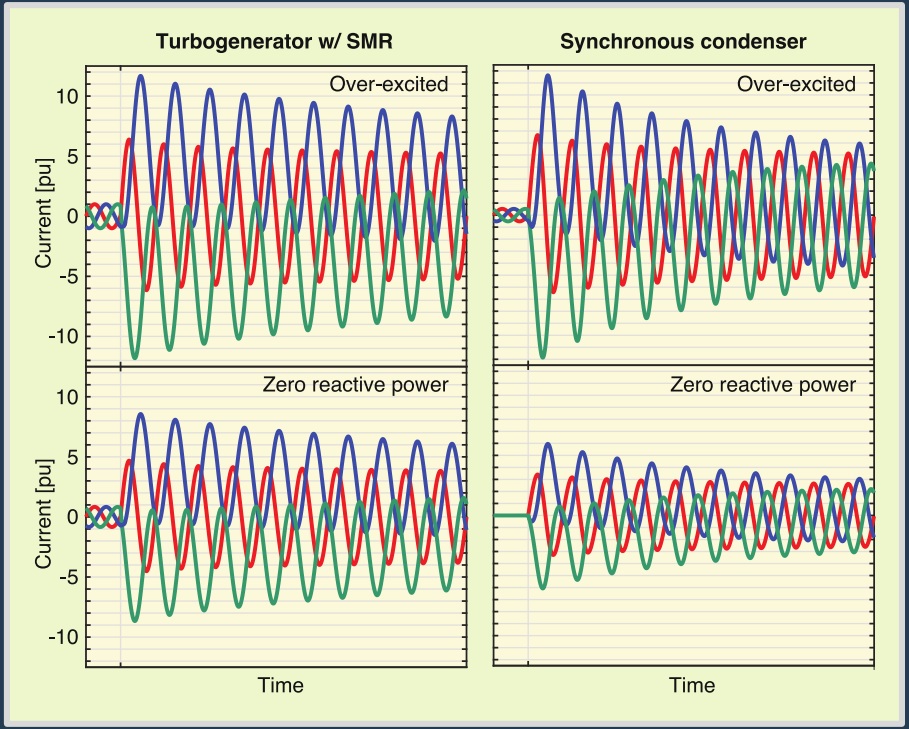




Source: J. K. Nøland, *et al.*, "Running Renewable-Rich Power Grids," *IEEE Electrification Magazine*, December 2024.

SMRs vs. SynCons

Grid strength of SMRs vs. SynCons during grid faults. Sufficient short circuit level help clear out grid faults.



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3. THE ROLE OF NUCLEAR ENERGY IN THE EUROPEAN POWER SYSTEM

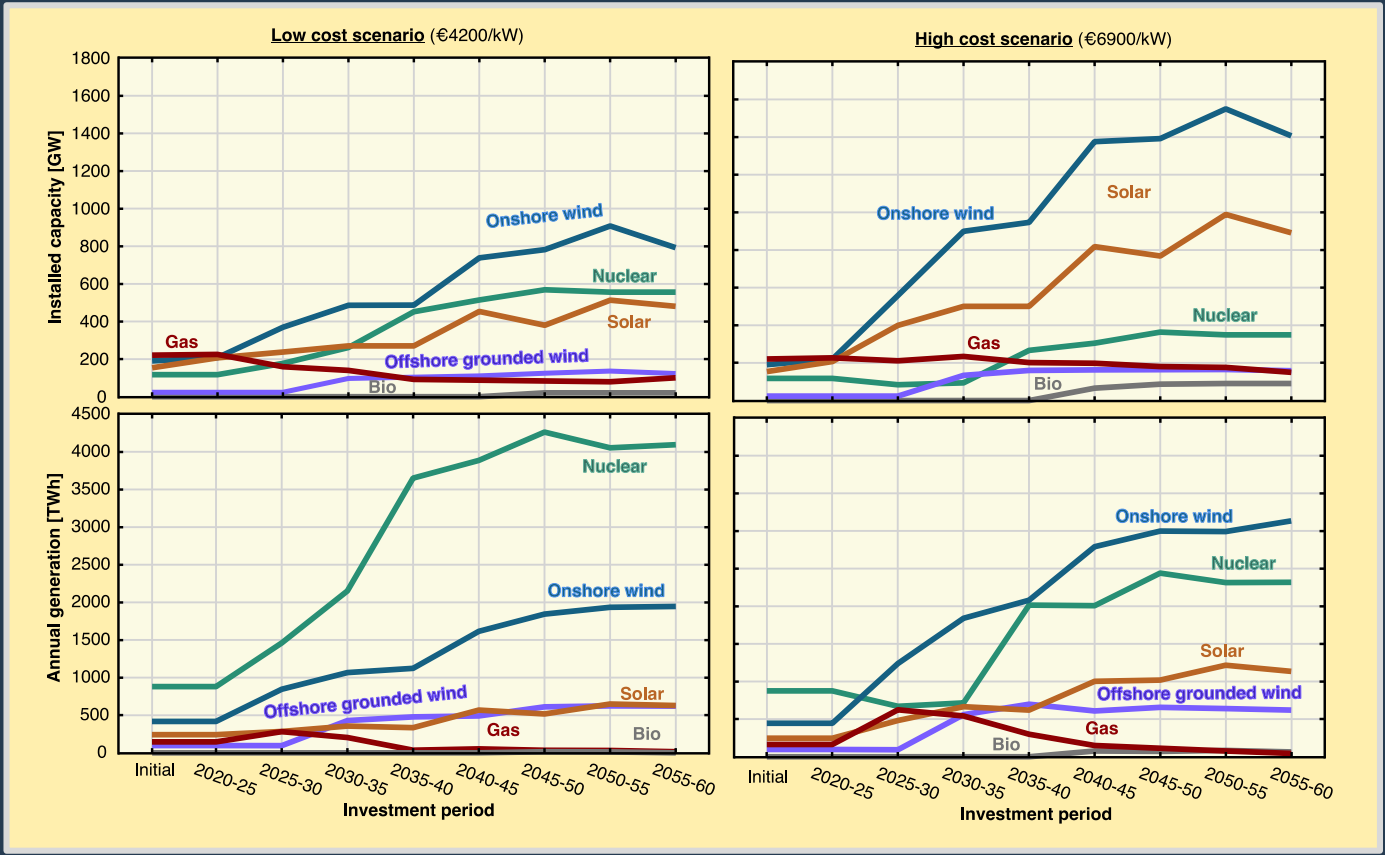
Why focus on nuclear?

*"The fourth constraint was that **no new nuclear** or fossil-based power plants could be installed after 2015 **due to sustainability reasons**."*

-Energy system paper with 138+ citations

European capacity expansion analysis overview

Source: M. Hjelmeland, *et al.*, “The role of nuclear energy and baseload demand in capacity expansion planning for low-carbon power systems,” *Applied Energy*, January 2025, doi: https://doi.org/10.1016/j.apenergy.2024.124366



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Summary of results

Nuclear OCC [€/kW]	System Cost [€/MWh]	Land Use [10^3 km^2]	Bio [%]	Gen. [TW]	VRE [%]	Nuclear [%]	Curtail. [TWh]	Grid [GW]	Storage [GW]	Storage [TWh]
3200 (Very low)	38.2	134.1	8.3	2.6	53.4	24.6	77.3	392.0	87.8	2.6
4200 (Low)	40.6	204.4	20.9	3.1	60.9	17.0	130.0	441.7	107.6	2.7
5300 (Medium)	42.5	283.7	33.3	3.4	66.5	11.9	200.1	488.5	146.2	2.8
6900 (High)	44.3	404.9	47.0	3.9	72.0	7.3	334.5	515.3	223.9	2.9

Source: M. Hjelmeland, *et al.*, "The role of nuclear energy and baseload demand in capacity expansion planning for low-carbon power systems," *Applied Energy*, January 2025, doi: https://doi.org/10.1016/j.apenergy.2024.124366

Expensive nuclear scenario implies more transmission capacity

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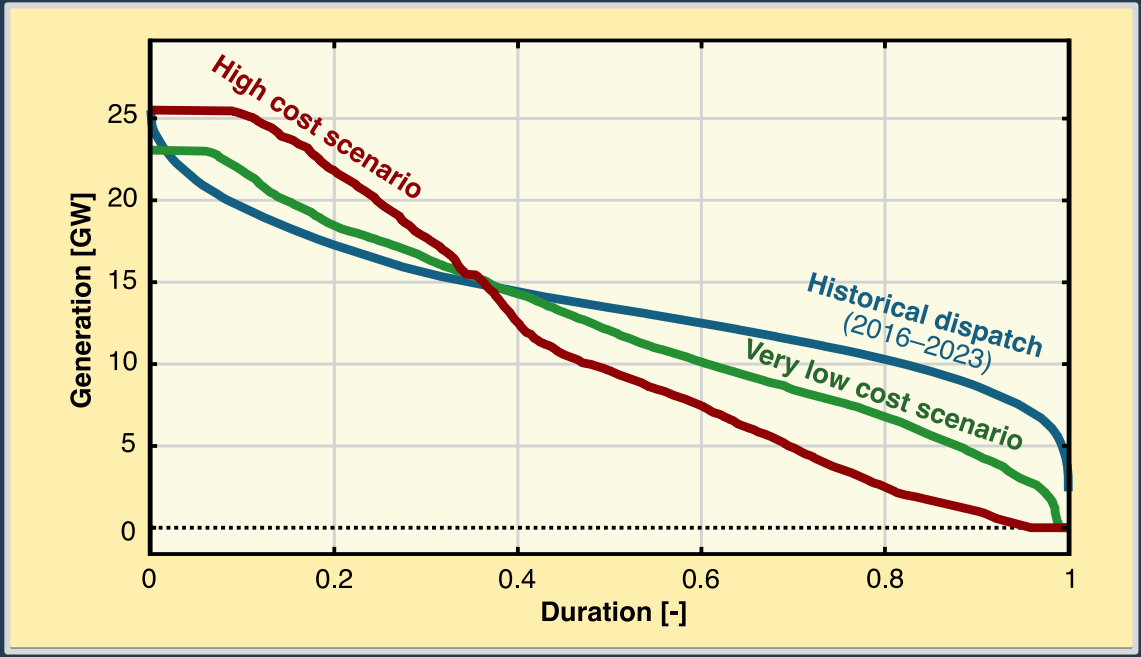
Low share of nuclear requires more flexible hydropower operations



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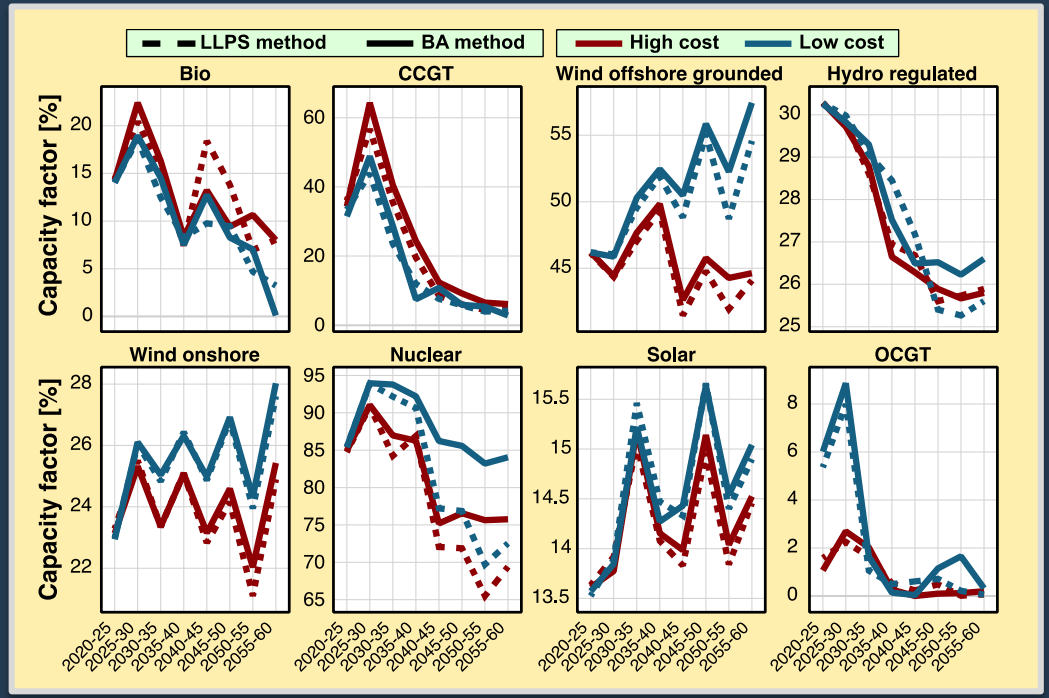
Reduction of nuclear capacity factor



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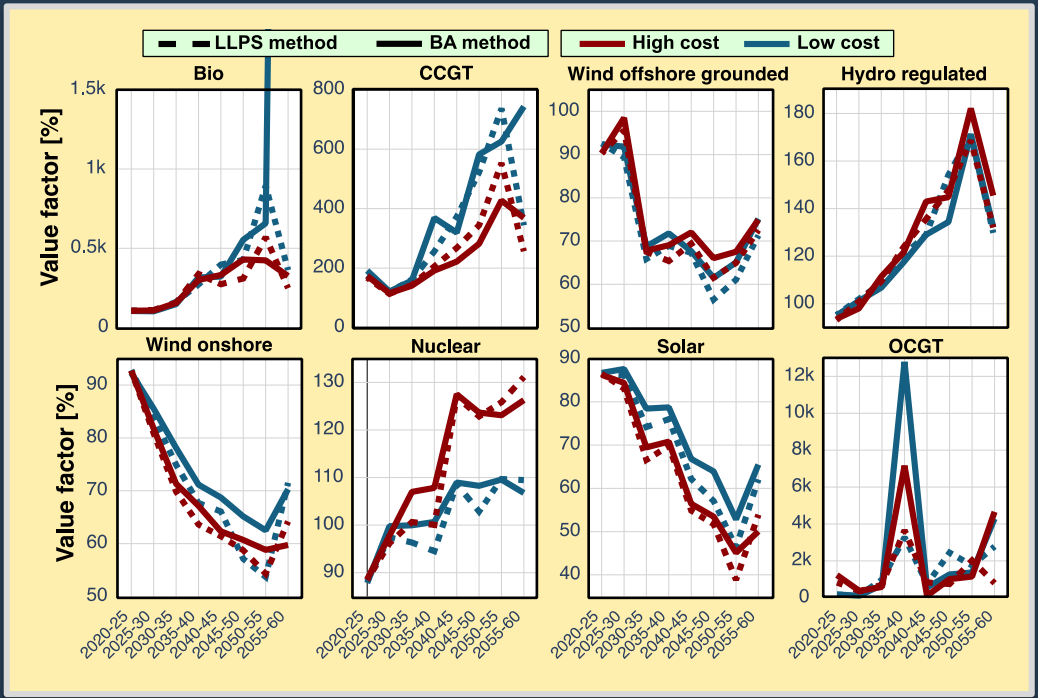
.. but increased value factor



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4. CONCLUSIONS AND KEY TAKEAWAYS

Closing remarks

- Nuclear energy will be the most important firm synchronous power source in the energy transition
  - Its system-bearing ancillary services come in addition to its power generation and are often not valued

- Even in a high nuclear cost scenario, nuclear will play an important role in the European power system
  - Competitive nuclear reduces system cost, land use, air pollution, curtailment of renewables, energy storage, and transmission

Thank you!