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Scenario analysis using electricity market modelling – and limitations

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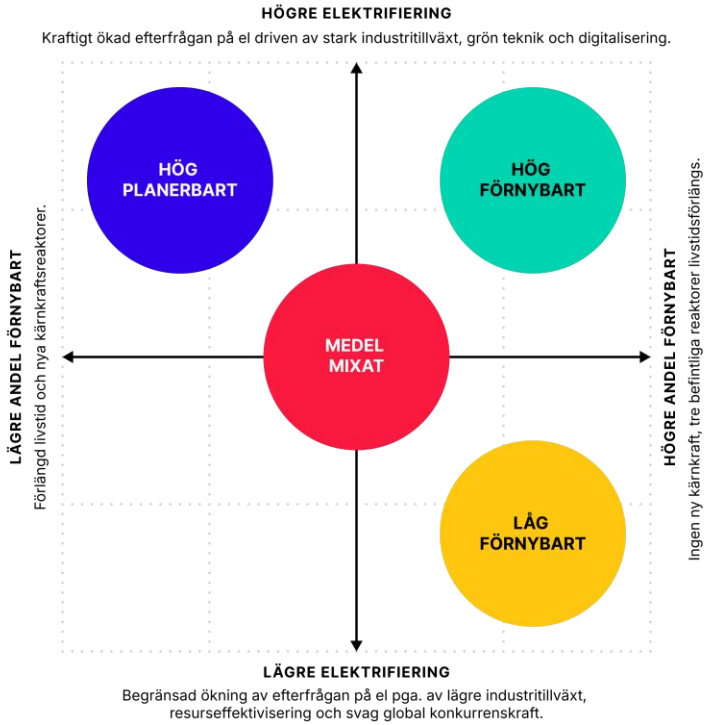
Long-term Market Analysis (LMA)

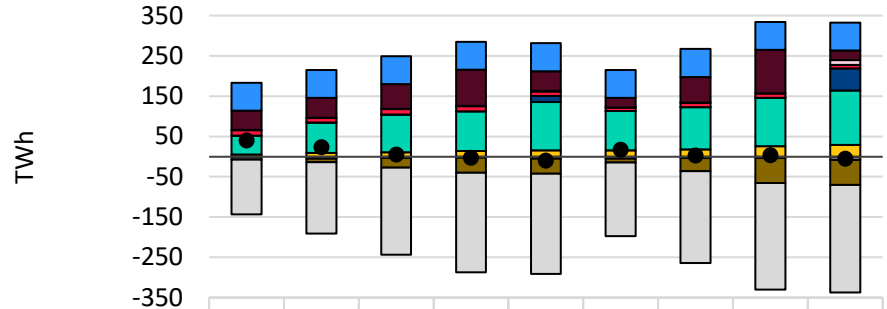
- Long-term scenarios for Swedish (European) power system
- Need for transmission infrastructure
  - Simulate socio-economic welfare of transmission projects for cost-benefit analysis
- Study implications of different systems for:
  - Rerquirements of balancing resources
  - System inertia
  - Power system adequacy
  - Electricity prices
- Input to European-wide studies by ENTSO-E

Latest LMA scenarios: LMA 2026

LMA 2026 Scenarios

- Four scenarios differentiated by consumption and production mix
- Production capacity determined by investment optimization

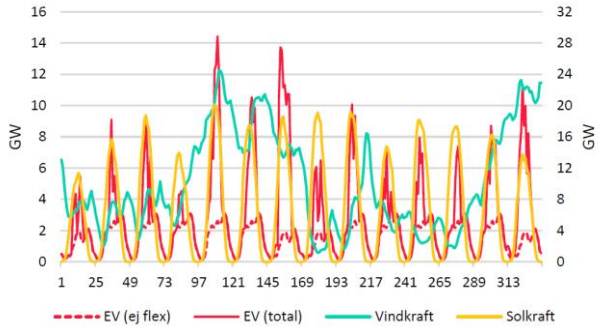


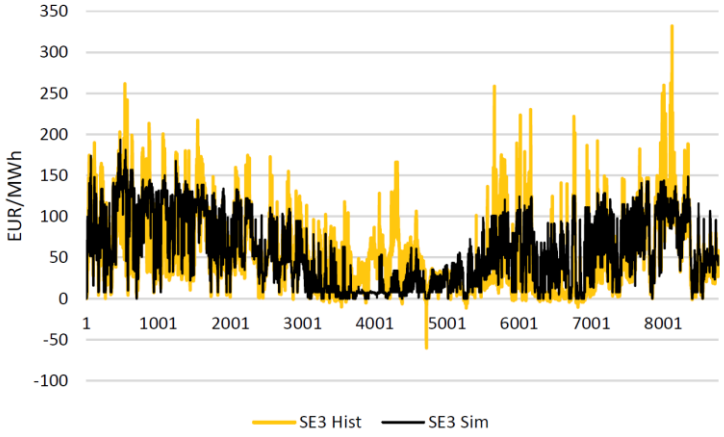


	-	LF	MM	HP	HF	LF	MM	HP	HF
	2026	2040				2050			
Prod. total	183	215	249	285	282	215	267	334	333
Kons. total	-136	-186	-240	-284	-286	-192	-260	-327	-329
Vattenkraft	69	69	69	69	69	69	69	69	69
Kärnkraft	48	49	61	89	49	24	64	108	24
Övrig termisk	1	0	1	1	1	0	0	0	12
Kraftvärme	13	11	13	13	11	8	11	11	8
Vindkraft hav	1	0	0	0	14	0	0	0	55
Vindkraft land	47	76	94	98	121	97	105	120	135
Solkraft	5	9	11	14	15	16	18	26	29
Kons. övrig	-136	-177	-216	-247	-248	-183	-228	-265	-267
Kons. vätgas	0	-9	-24	-37	-38	-9	-33	-62	-62
Spill	-8	-5	-3	-3	-5	-5	-4	-4	-8
Nettoexport	40	24	5	-3	-10	17	2	3	-5

Electricty Market Modelling

- Model price areas in electricity market market:
  - 365 days, 44 weather years, multiple scenarios

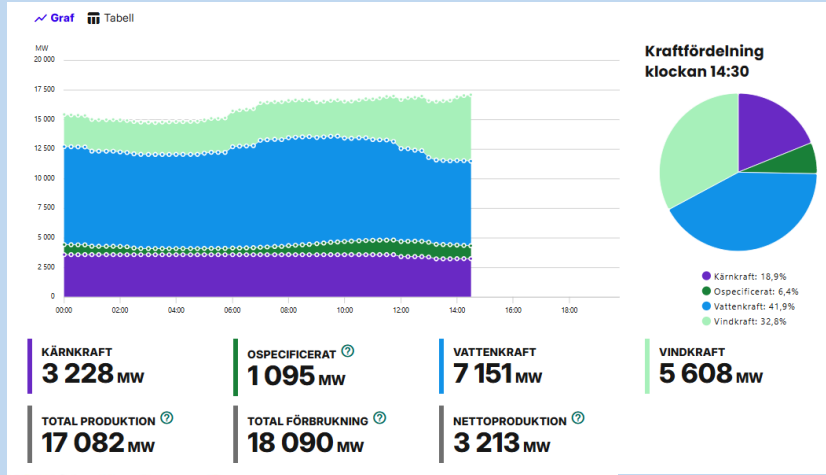


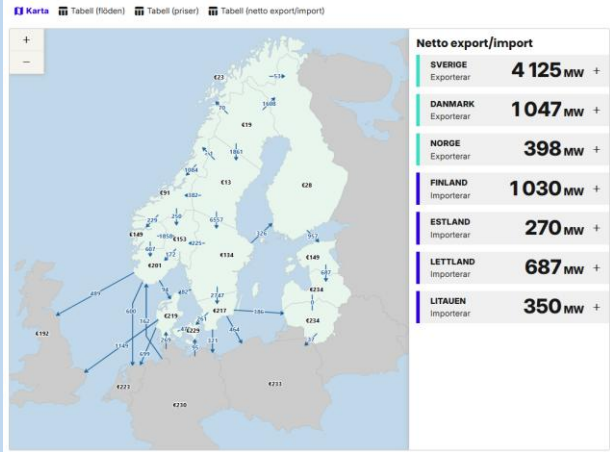


Input data
Validation

- Electricity market: 24 hours at a time, 1 forecast

Kontrollrummet – the (almost) real world
https://www.svk.se/om-kraftsystemet/kontrollrummet/





Modelling limitations

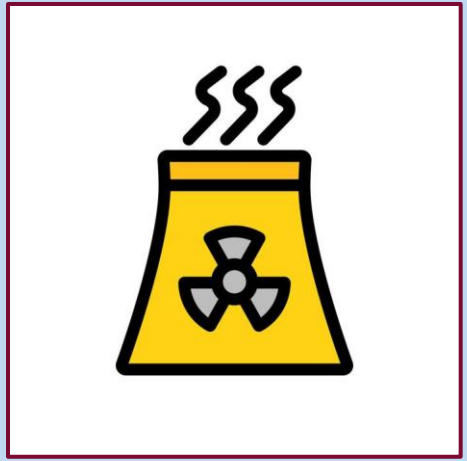
Model results

Lowest cost system subject to:

- Hourly energy balance
- Technical restrictions on power plants
- Grid constraints (NTC/flow-based/line flows)
- System constraints (reserves, stability, etc.)

Usually does not consider

- Detailed grid requirements, N-1 security
- Intra-hour variability
- Uncertainty due to forecast errors
- Voltage stability
- Frequency stability



Nuclear energy contributes to all of these!

How to consider these aspects to ensure we really find a cost-optimal system?

- Incorporate into investment optimization
- Do detailed ex-post evaluation of scenarios

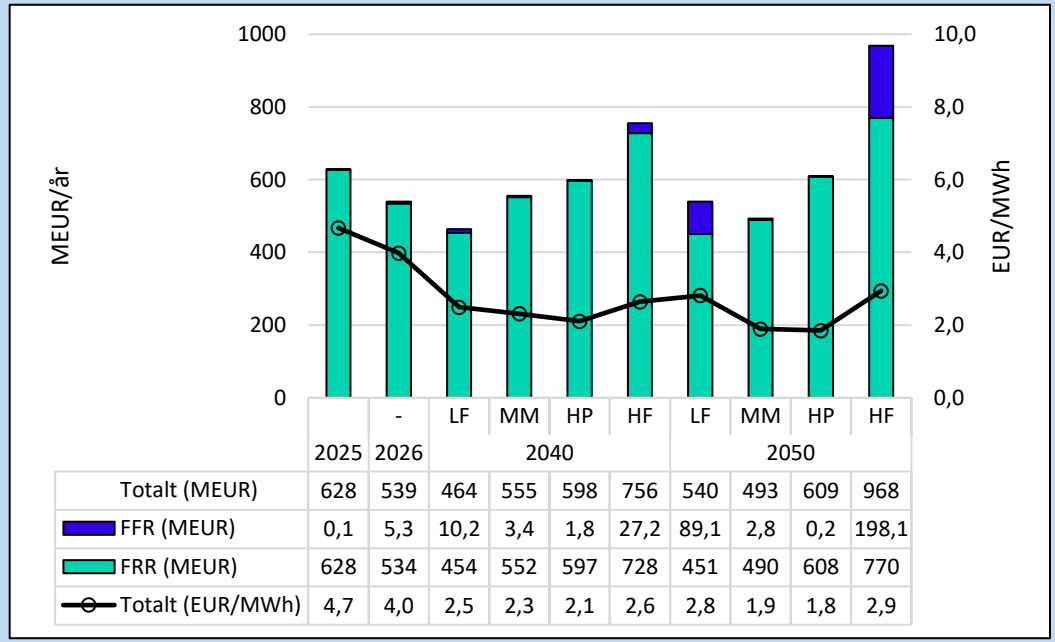
System costs in LMA 2026

Forecast uncertainty

- Estimate volume of reserves (FRR) needed to cover forecast uncertainty
- Quantify costs by assuming FRR needs met by batteries

Inertia and frequency stability

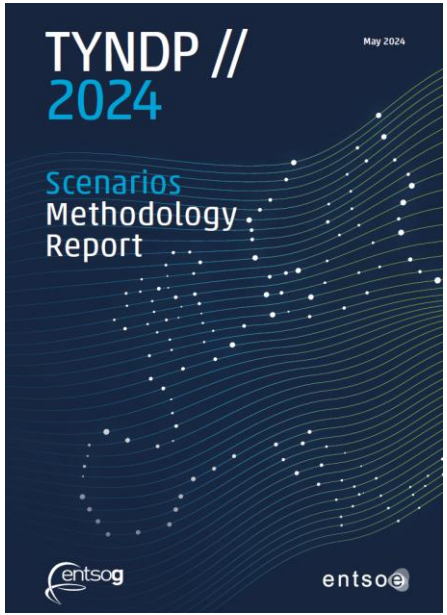
- Estimate system inertia
- Determine reserves (FFR) and renewable curtailment needed to guarante fast frequency stability
- Quantify costs of reserves and curtailment



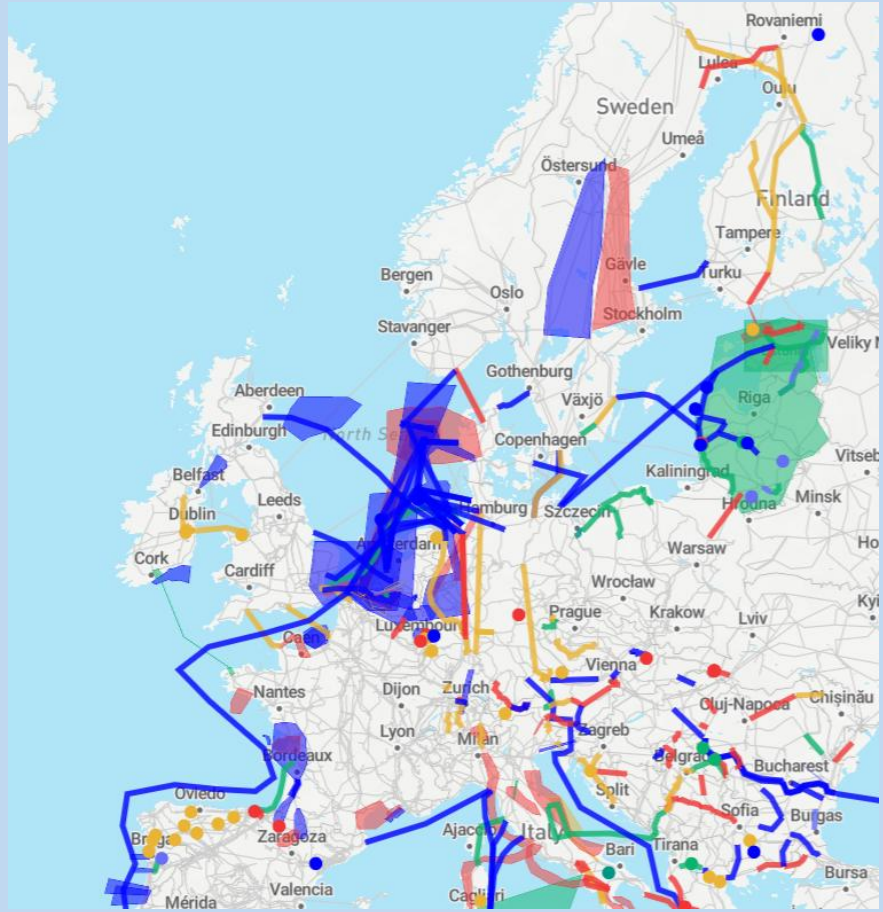
	2025	2026	2040 LF	2040 MM	2040 HP	2040 HF	2050 LF	2050 MM	2050 HP	2050 HF
Totalt (MEUR)	628	539	464	555	598	756	540	493	609	968
FFR (MEUR)	0,1	5,3	10,2	3,4	1,8	27,2	89,1	2,8	0,2	198,1
FRR (MEUR)	628	534	454	552	597	728	451	490	608	770
Totalt (EUR/MWh)	4,7	4,0	2,5	2,3	2,1	2,6	2,8	1,9	1,8	2,9

TYNDP Scenarios

- Developed collectively by European TSOs for electricity and gas through ENTSO-E and ENTSO-G
- Used to perform cost-benefit analysis of transmission projects and allocated EU funds from Connecting Europe Facitlity

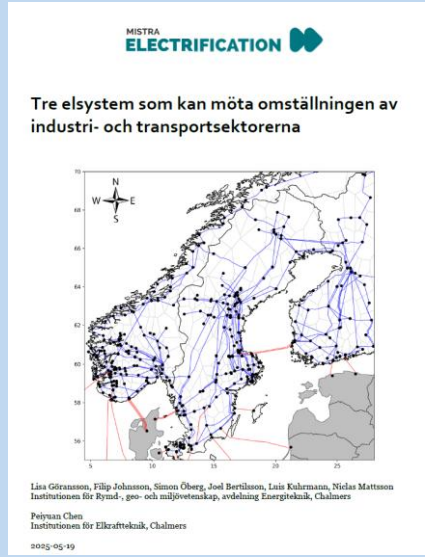


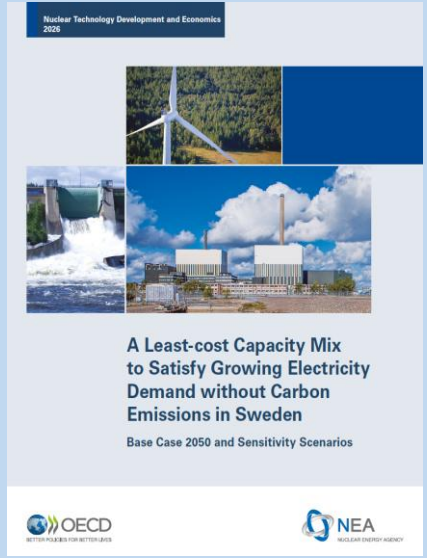
TYNDP 2024 Project map for electricity



Other Studies

- Mistra Electrification, 2025, ”Tre elsystem som kan möta omställningen av industri- och transportsektorerna”
  Link: https://research.chalmers.se/en/publication/546563
- Quantified Carbon, 2025, ”Swedish Power Systems Robust for 300 TWh”
  Link: https://www.quantifiedcarbon.com/clients/swedish-power-systems-robust-for-300twh
- Nuclear Energy Agency, 2026, “A Least-cost Capacity Mix to Satisfy Growing Electricity Demand without Carbon Emissions in Sweden”
  Link: https://www.oecd-nea.org/jcms/pl_116142/a-least-cost-capacity-mix-to-satisfy-growing-electricity-demand-without-carbon-emissions-in-sweden?details=true





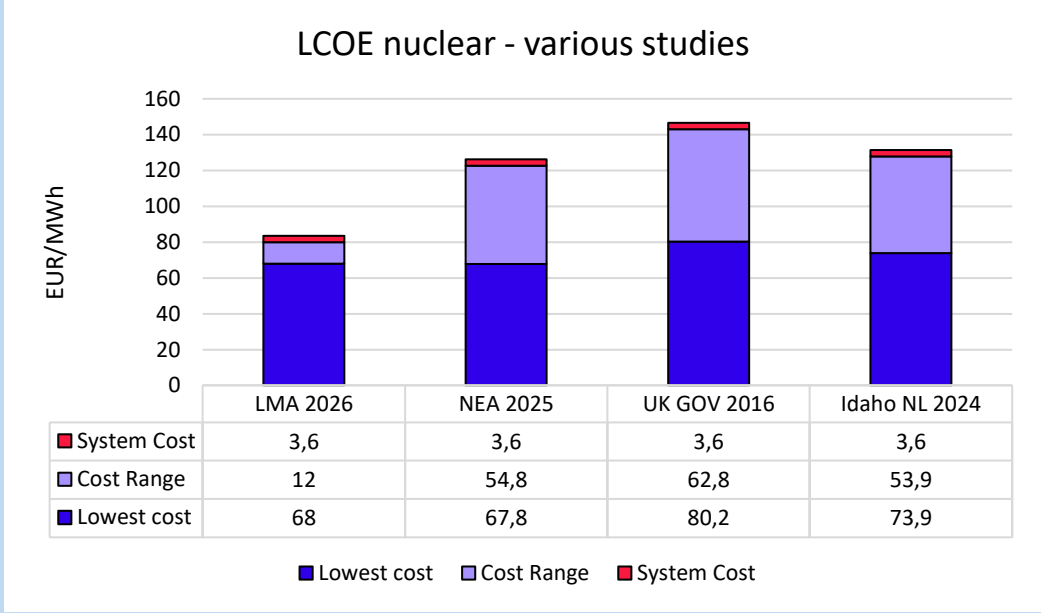
Cost uncertainty – LCOE vs System costs

Two major uncertainties regarding nuclear in energy system studies:

- Build cost of nuclear (LCOE)
- Effect on system costs

Effect on system costs of varying nuclear contribution, for systems with ~300 TWh consumption in Sweden

Cost	EUR/MWh	Nuclear range	Source
Transmission grid	2,5	0-150 TWh	Scenarioanalys 2050, QC
Balancing FFR + FRR	1,1	24-108 TWh	LMA 2026
Total	**3,6**		



Uncertainty of system costs is small compared to uncertainty in nuclear LCOE!

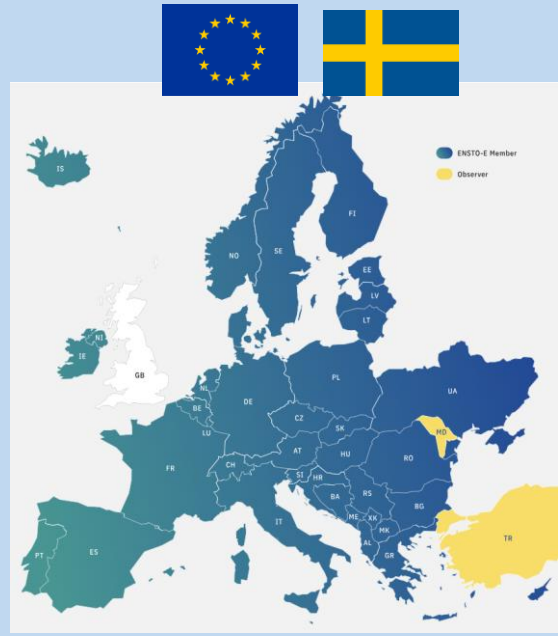
Are we moving towards more central planning of power systems?

Svenska kraftnät:

- **June 30, 2025:** Svk's instruction updated to give increased responsibility for coordingating long-term planning of power system
  May 21, 2026: Svk to prepare for certification as system responsible for transmission infrastructure for hydrogen

EU Grid Package (December 10, 2025):

- Commission to develop Central Reference Scenario to identify infrastructure needs and strengthen coordination between national and European planning



Greater reliance on top-down energy system modelling means quality of scenarios is essential!

THE END

Questions?

Feel free to contact me:

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