European Resource Adequacy Assessment (ERAA) 2023 – Methodology and results

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Background

- ERAA is an ENTSO-E legal mandate (Article 23 of Electricity Regulation), which aims to identify resource adequacy concerns by assessing adequacy of the electricity system to supply current and projected demands.
- It is a full pan-European monitoring assessment of power system resource adequacy, unique on its kind, based on a state-of-the-art probabilistic analysis, looking up to a decade ahead.
- Stepwise implementation of the methodology already began with ERAA 2021, with new improvements in the methodology in each edition (2022, 2021).
- ERAA 2023 aims to be an effective tool to identify adequacy risks, and includes an **enhanced Economic Viability Assessment** and advanced **Flow-Based market coupling** incorporated in the central reference scenarios.
- By proactively and factually identifying any system adequacy challenges, ERAA supports decision-makers in ensuring secure, affordable and sustainable energy to citizens and industries.

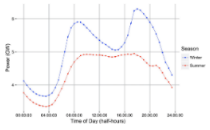
The framework of ERAA 2023

TSO Data and NECPs

PEMMDB
Net Generation Capacities

Market Coupling
Net Transfer Capacities
Flow-Based

PECD
Capacity Factors
Hydro Database
Temperature profiles

DEMAND

Native demand forecasts

Economic Viability Assessment (EVA)

- Stochastic overall costs minimization

Central Reference Scenario

- Include EVA entry/exit of market capacity

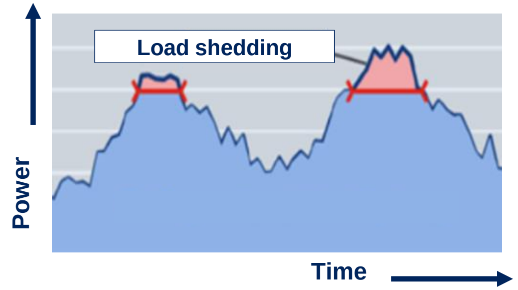
ED Model: Monte Carlo Simulation

1. N years of independent climate data
x
2. M random draws for unplanned outages
3. M x N Monte Carlo sample years

Adequacy Metrics

$$EENS = \frac{1}{M \times N}\sum_j ENS_j$$

$$LOLE = \frac{1}{M \times N}\sum_j LLD_j$$



LoLE* = Loss Of Load Expectation [hrs/year]:
average number of hours in which the demand exceeds the generation and import capacity in a market area.

EENS = Expected Energy Not Served [GWh/year]:
average energy not supplied when the demand exceeds the generation and import capacity in a market area.

* In Europe, the LOLE criterion expresses the unserved load in terms of an average number of hours per year. This is equal to the definition of Loss Of Load Hours (LOLH) commonly used in North America.

ERAA 2023 – Methodology „in a nutshell“

Target Years

- 2025, 2028, 2030, 2033

Probabilistic Approach

- 35 climate years
- 15 forced outage patterns

EVA

- Investment modelling (decommissionings, mothballing, life extension, new built)
- Closed-loop optimization covering all target years
- Climate year clustering ⇒ 3 representative, weighted climate years combined with forced outage patterns
- Determination of the economically viable generation, storage and demand-side response portfolio

Adequacy (Economic Dispatch)

- probabilistic resource adequacy analysis by a combination of all climate years and forced outage patterns ⇒ Economic Dispatch (ED) runs for 525 „Monte Carlo“- years
- determination of „Loss Of Load Expectation“ – LOLE (h/a)

EVA, how is it done?

EVA input

1

- Technologies subject to EVA:
  - All thermal generators
  - RES, Nuclear and Hydrogen treated as policy technologies
  - New gas, batteries and explicit DSR as expansion candidates
- Techno-Economic parameters
  - CAPEX
  - WACC and risk premium
  - Fixed and variable O&M costs
  - Commodity prices
  - Expansion potentials
  - Market price caps

Modelling

2

- Investment model
  - Multi-year complexity
  - Stochastic approach
  - Selection of climate years and weights
  - Cross-border contribution

EVA results

3

- Capacity likely to stay/leave/enter the market
- Regional impact
- Definition of the central reference scenario

Acronyms: Renewable Energy Sources (RES), Capital Expenditure (CAPEX), Weighted Average Cost of Capital (WACC), Operation & Maintenance (O&M), Demand Side Response (DSR)

EVA model formulation in Plexos*

Objective Function of the “Cost Minimization Approach”

The objective function of LT Plan seeks to minimize the Net Present Value (NPV) of all future costs:

$$\sum_{y}\sum_{g} DF_y * (BuildCost_g * GenBuild_{(g,y)})$$

$$+\sum_{y} DF_y \left[FOMCharge_g * 1000 * PMAX_g * \left(Units_g + \sum_{i\leq y} GenBuild_{g,i}\right)\right]$$

$$+\sum_{t} DF_{t\in y} * L_t \left[VOLL * ENS_t + \sum_{g}(SRMC_g * GenLoad_{g,t})\right]$$

build cost

+

fixed operations and maintenance costs

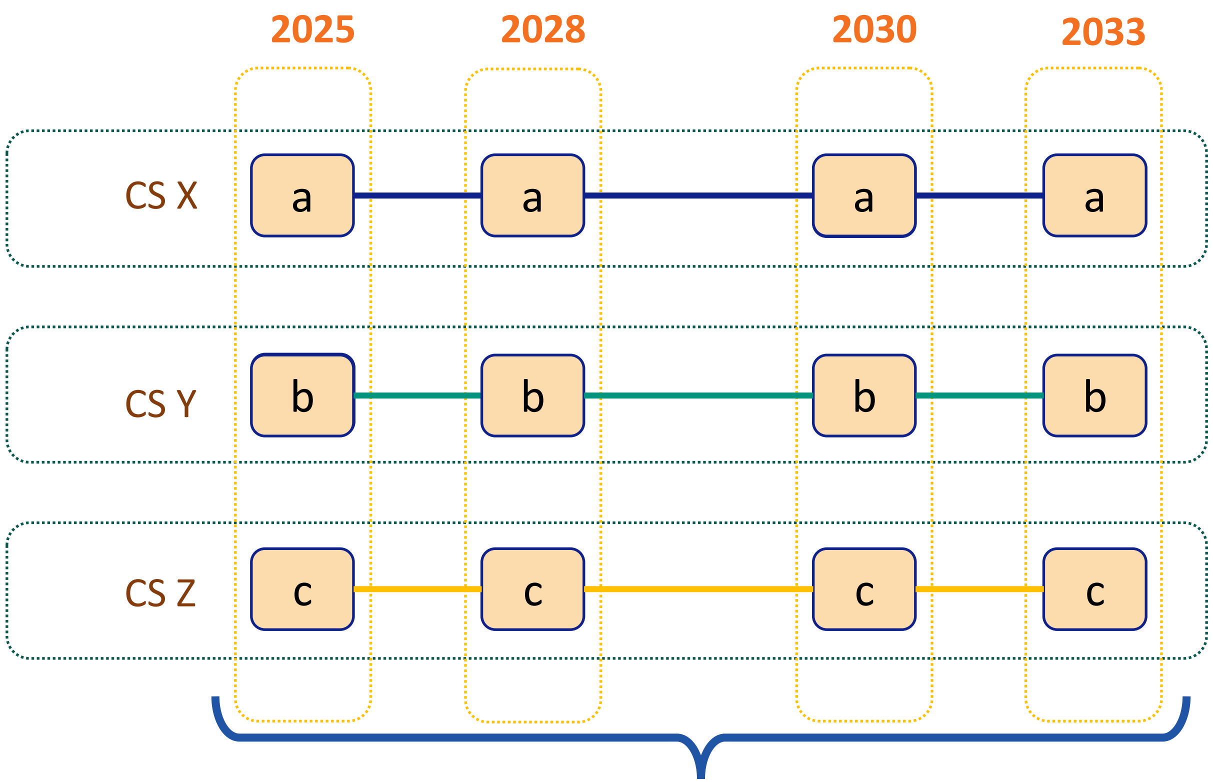
+

production and unserved energy costs

* main tool being used in the EVA in ERAA 2023

A probabilistic EVA is pursued, but the number of Climatic Scenarios is a challenge

- A climatic scenario (CS) is a sequence of a climatic year (CY - a,b,c in the example below) spanning all target years (2025 – 2033)
- The stochastic approach accounts for all CSs simultaneously and provides a single optimal solution



Closed-loop optimization with 1 solution

Computational challenge requires reducing the size of the optimisation problem

→ reduction of CS by clustering of CY

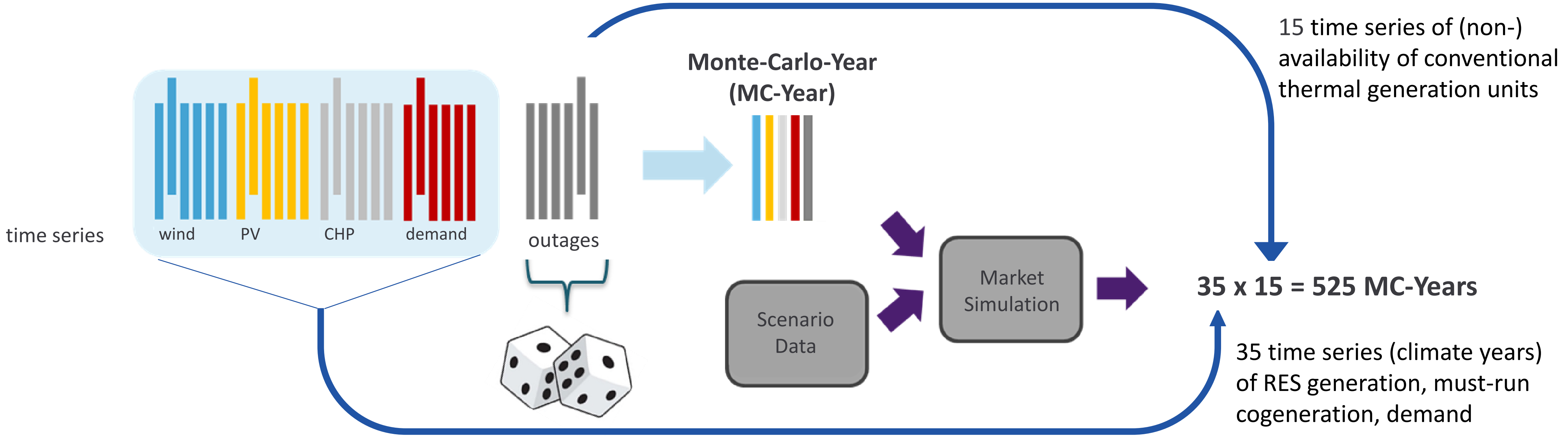
→ identification of one CY representing each cluster

→ weighting of clusters

CY weights	1985 (a)	1988 (b)	2003 (c)
Scenario A	8,9%	5,3%	85,8%
Scenario B	2,8%	5,7%	91,5%

- Scenario A: replicating average LOLE of ERAA 2022
- Scenario B: probability of occurrence of CY

Economic Dispatch (ED) by Monte-Carlo-Simulation to determine adequacy



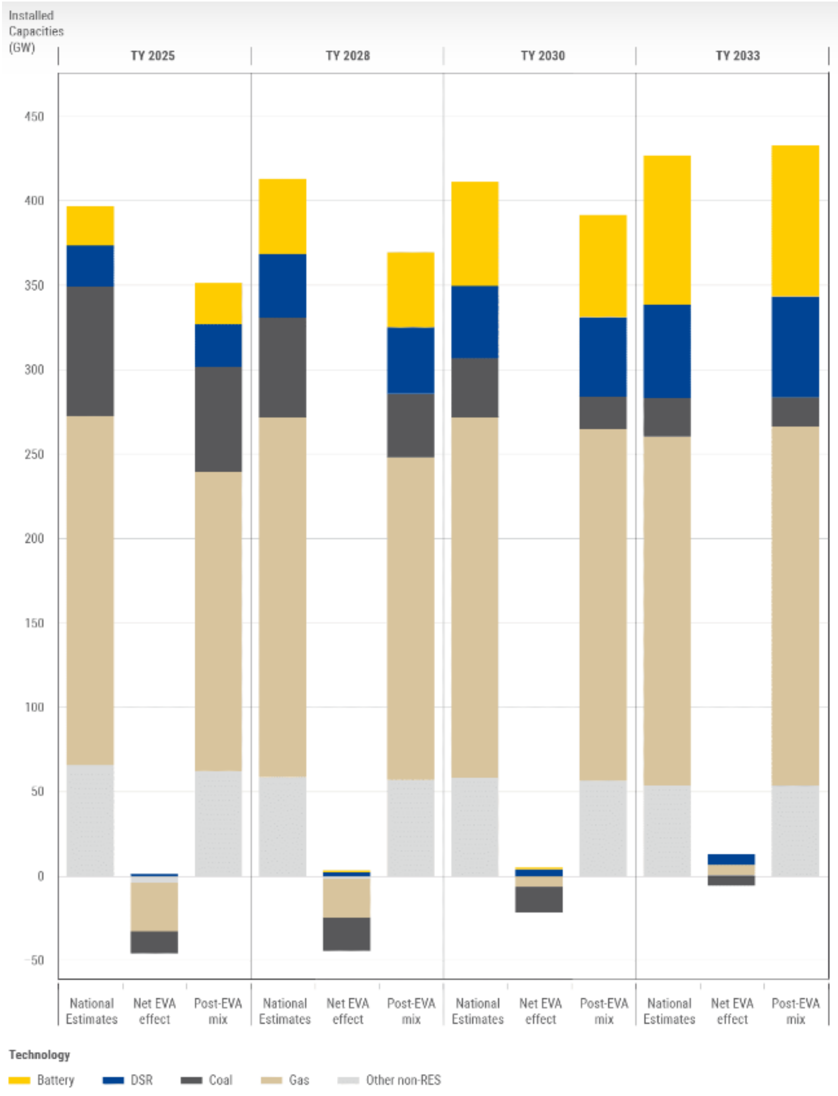
Adequacy metrics, of which values are concluded from the adequacy (ED) runs:

Loss Of Load Expectation (LOLE) [hrs/year]:
LOLE is defined as the expected (=average) value of Loss Of Load hours of all Monte-Carlo-Years.

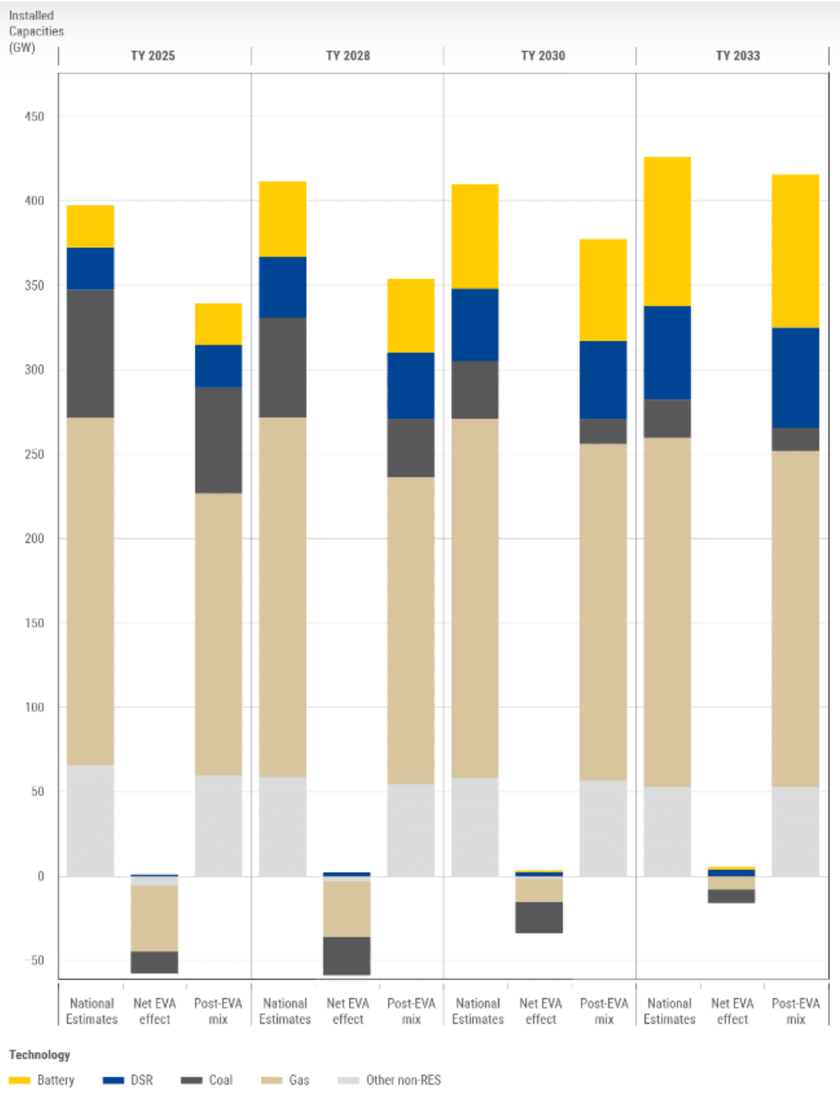
Expected Energy Not Served (EENS) [GWh/year]:
EENS is defined as the expected (=average) value of unserved energy demand during Loss Of Load hours of all Monte-Carlo Years.

EVA Results – Development of Installed Capacities (non-RES)

Scenario A



Scenario B



EVA Findings

- The investment model calculations results in a net decrease of thermal generation capacities in almost all target years in both scenarios.
- Only scenario A shows a net increase in 2033 driven by massive investments in gas generation capacities with H_2-readiness in Germany.
- Investments in battery storage and demand flexibilities increase in all target years in both scenarios.

Reliability Standard (RS) - Definition

Member state	Type of reliability standard	Value
Belgium[a]	LOLE (hours/year)	3.00
Cyprus[b]	LOLE (hours/year)	3.00
Czech Republic	LOLE (hours/year)	15.00
Estonia[c]	LOLE (hours/year)	9.00
Finland[d]	LOLE (hours/year)	2.10
France	LOLE (hours/year)	2.00
Germany[e]	LOLE (hours/year)	2.77
Greece	LOLE (hours/year)	3.00

Member state	Type of reliability standard	Value
Ireland (SEM)[f]	LOLE (hours/year)	8.00
Italy	LOLE (hours/year)	3.00
Luxembourg[g]	LOLE (hours/year)	2.77
The Netherlands	LOLE (hours/year)	4.00
Poland[h]	LOLE (hours/year)	3.00
Portugal	LOLE (hours/year)	5.00
Sweden	LOLE (hours/year)	0.99

$$\boldsymbol{RS = LOLE = \frac{CoNE}{VoLL}}$$

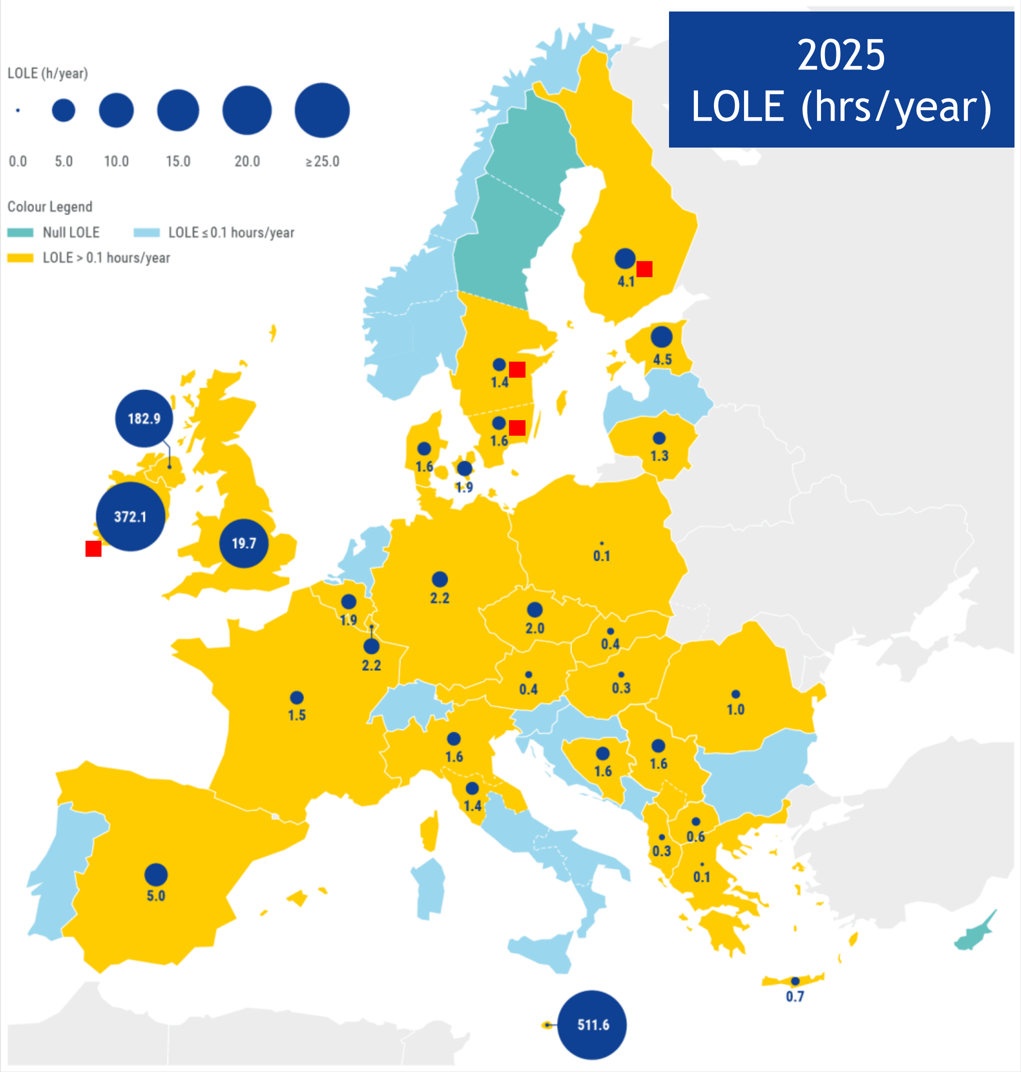
CoNE = Cost of New Entry

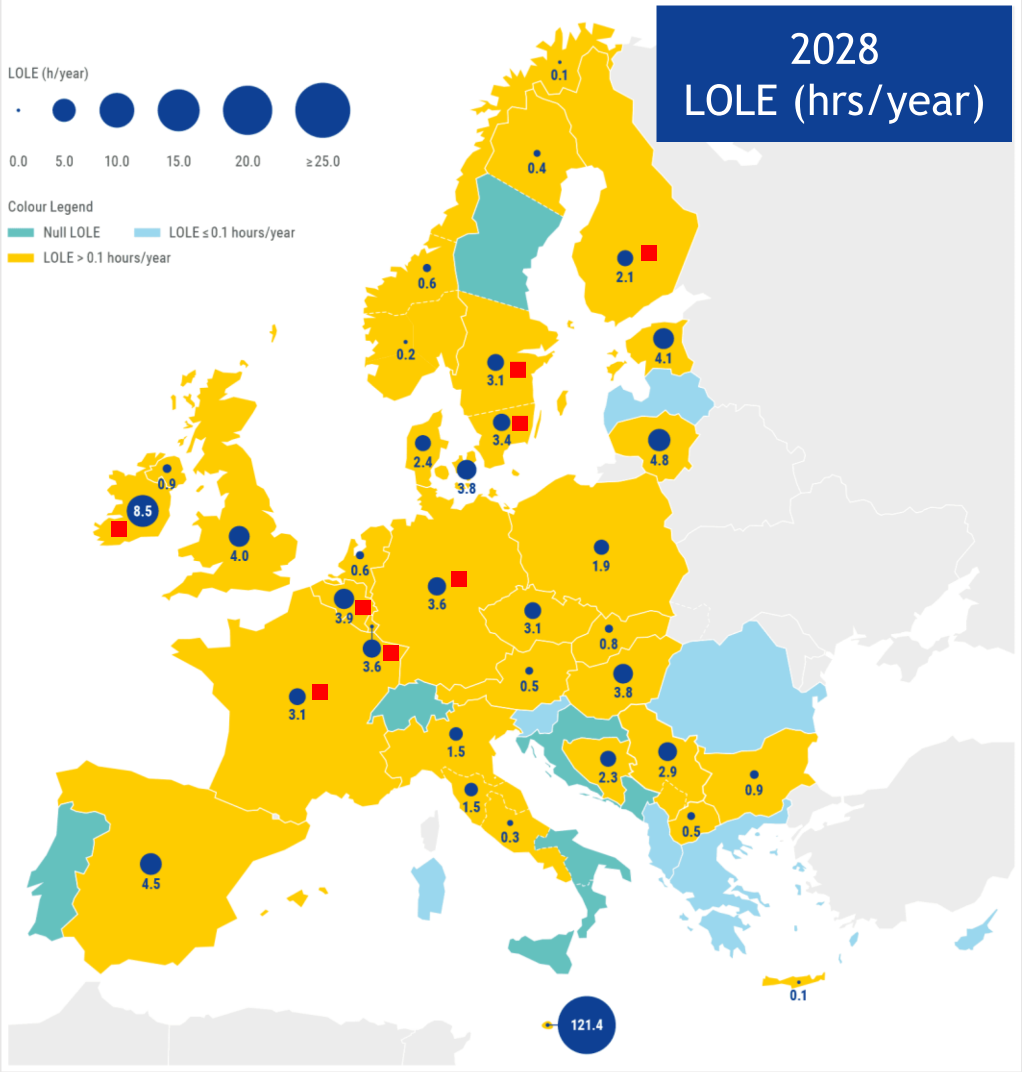
VoLL = Value of Lost Load, which customers would be willing to pay to avoid a loss of supply

Example: $$RS = \frac{CoNE}{VoLL} = \frac{50.000\ \frac{\frac{€}{MW}}{a}}{10.000\ \frac{€}{MWh}} = \boxed{\mathbf{5}\ \frac{\boldsymbol{h}}{\boldsymbol{a}}}$$

Adequacy results – Scenario A / Central reference

Adequacy risks appear in most European countries in Scenario A and the margins are tight. The scarcity risks tend to shift from the peripheral areas of Europe in 2025 to the central parts of the continent by 2033

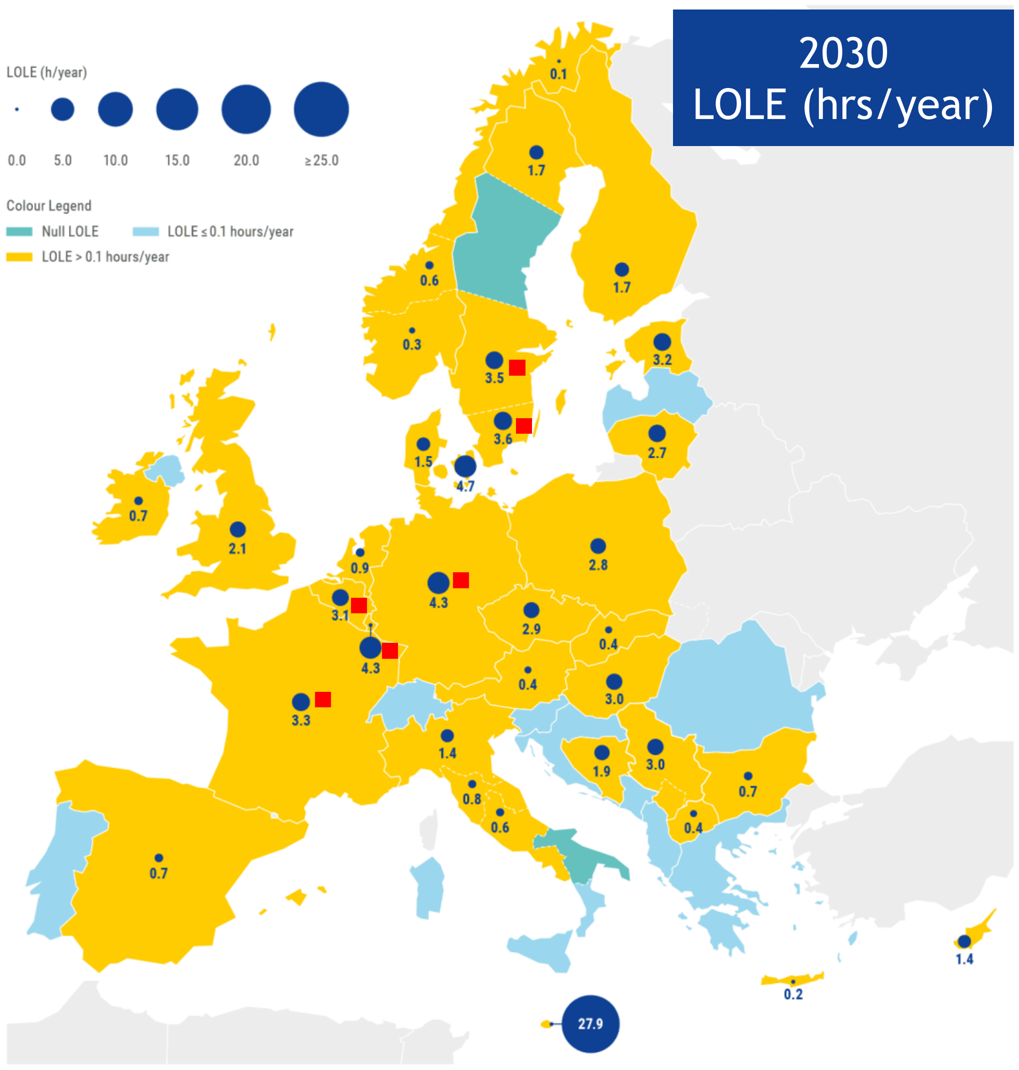


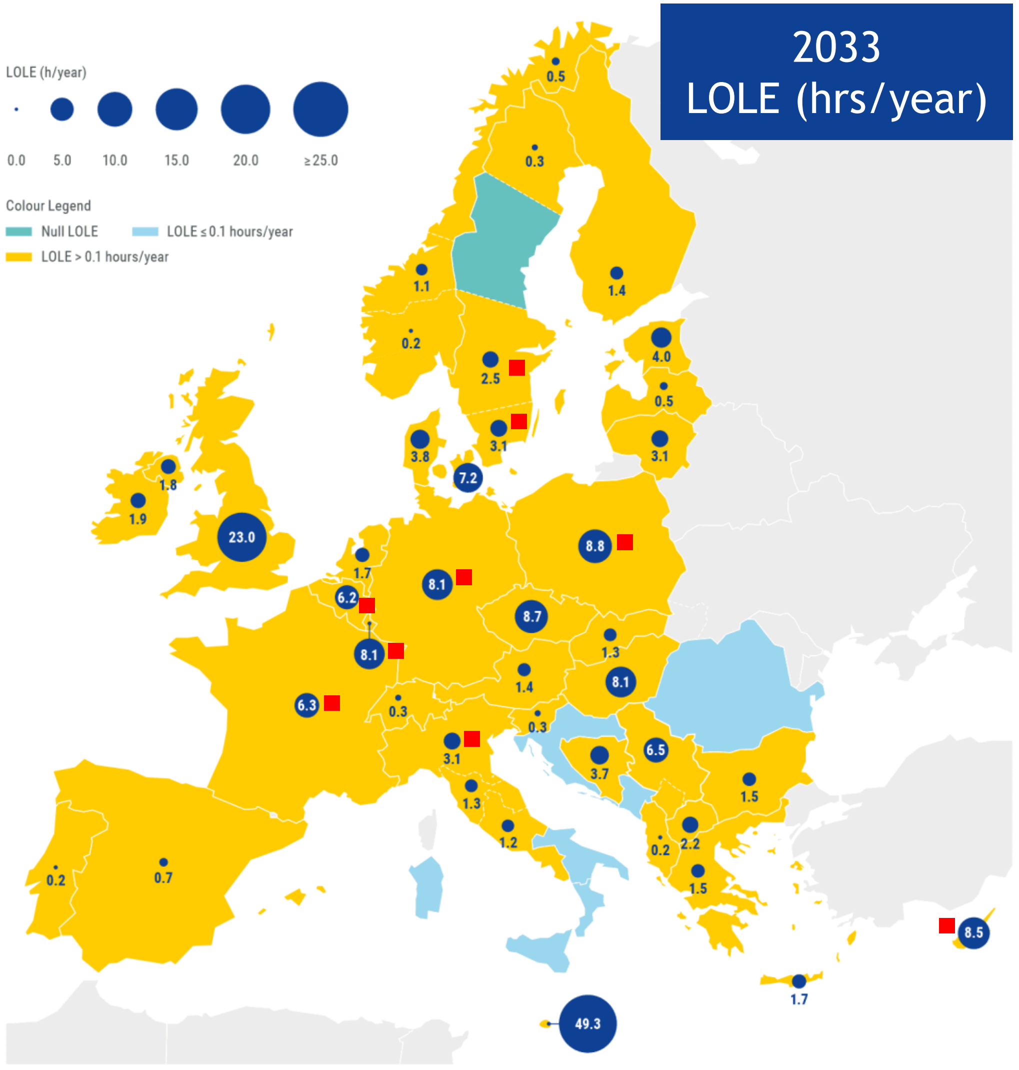


country / bidding zone, where a nationally defined reliability standard is exceeded

Adequacy results – Scenario A / Central reference (cont.)

Adequacy risks appear in most European countries in Scenario A and the margins are tight. The scarcity risks tend to shift from the peripheral areas of Europe in 2025 to the central parts of the continent by 2033

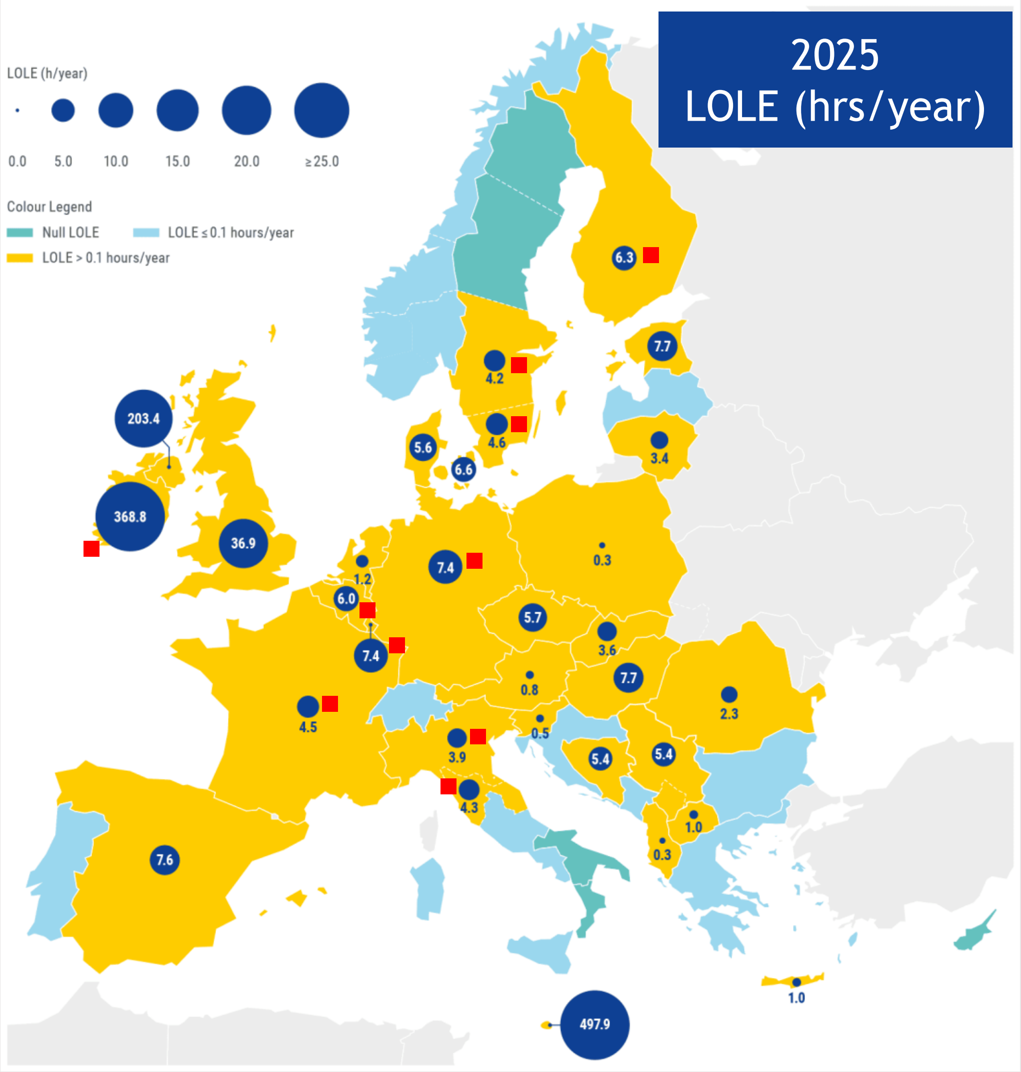


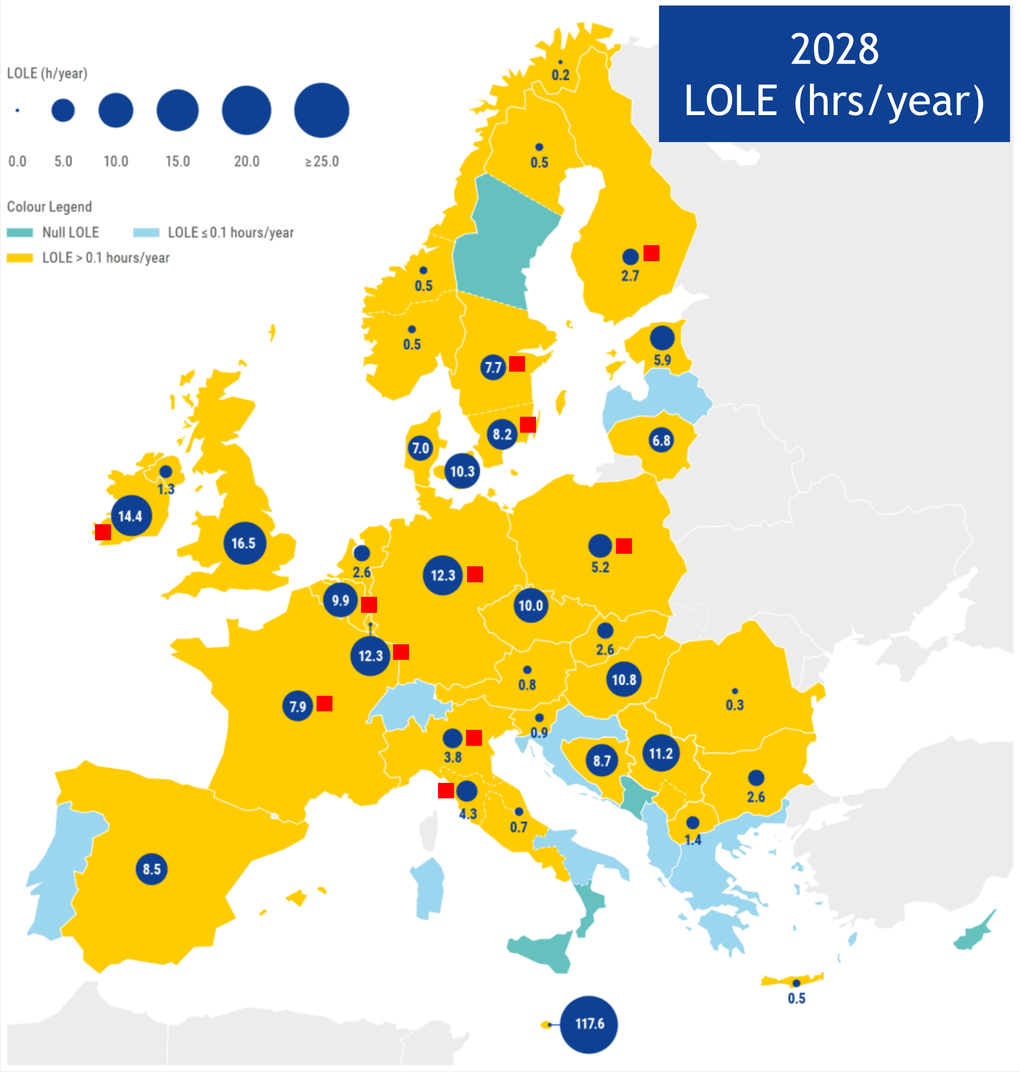


country / bidding zone, where a nationally defined reliability standard is exceeded

Adequacy results – Scenario B / Sensitivity

Adequacy risks are higher across Europe in this scenario and increase as we move from the short to mid-term.

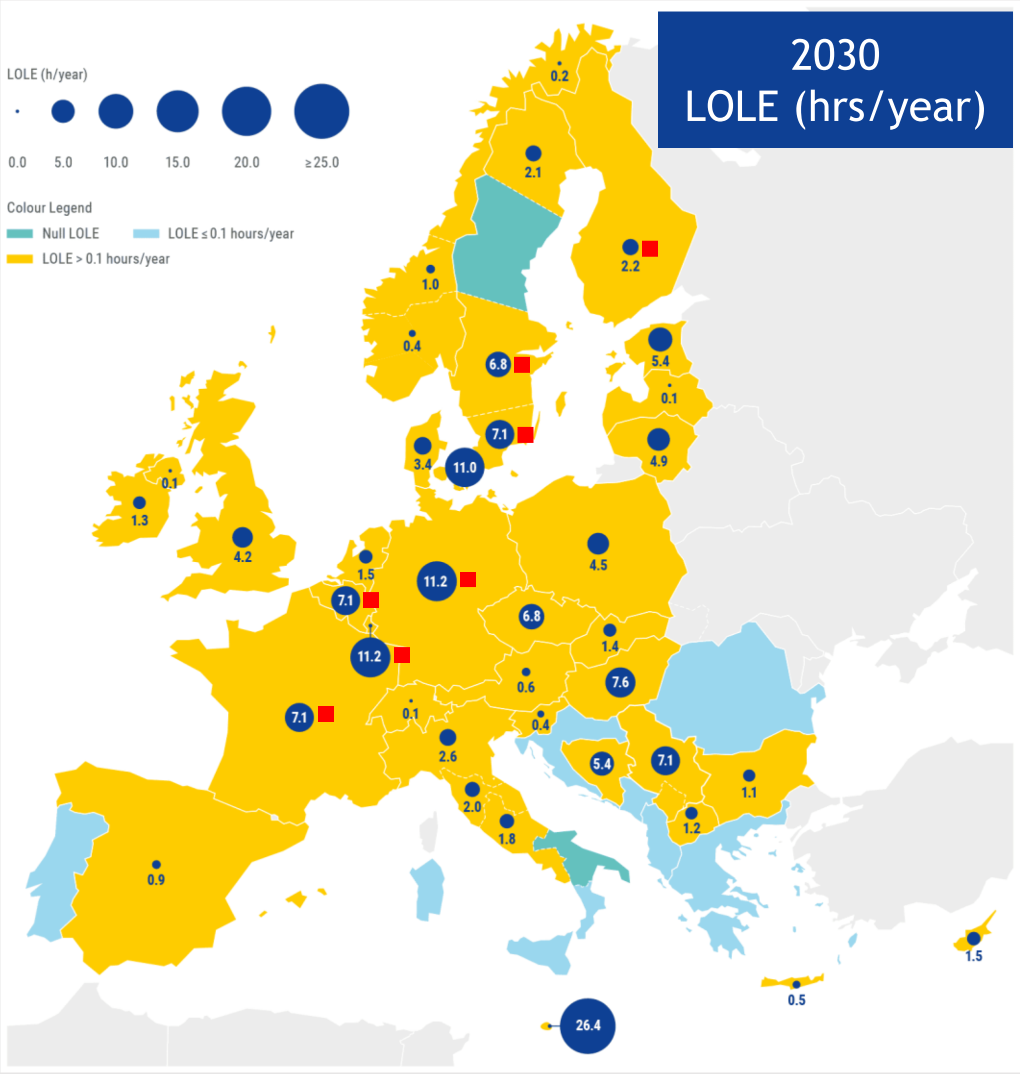


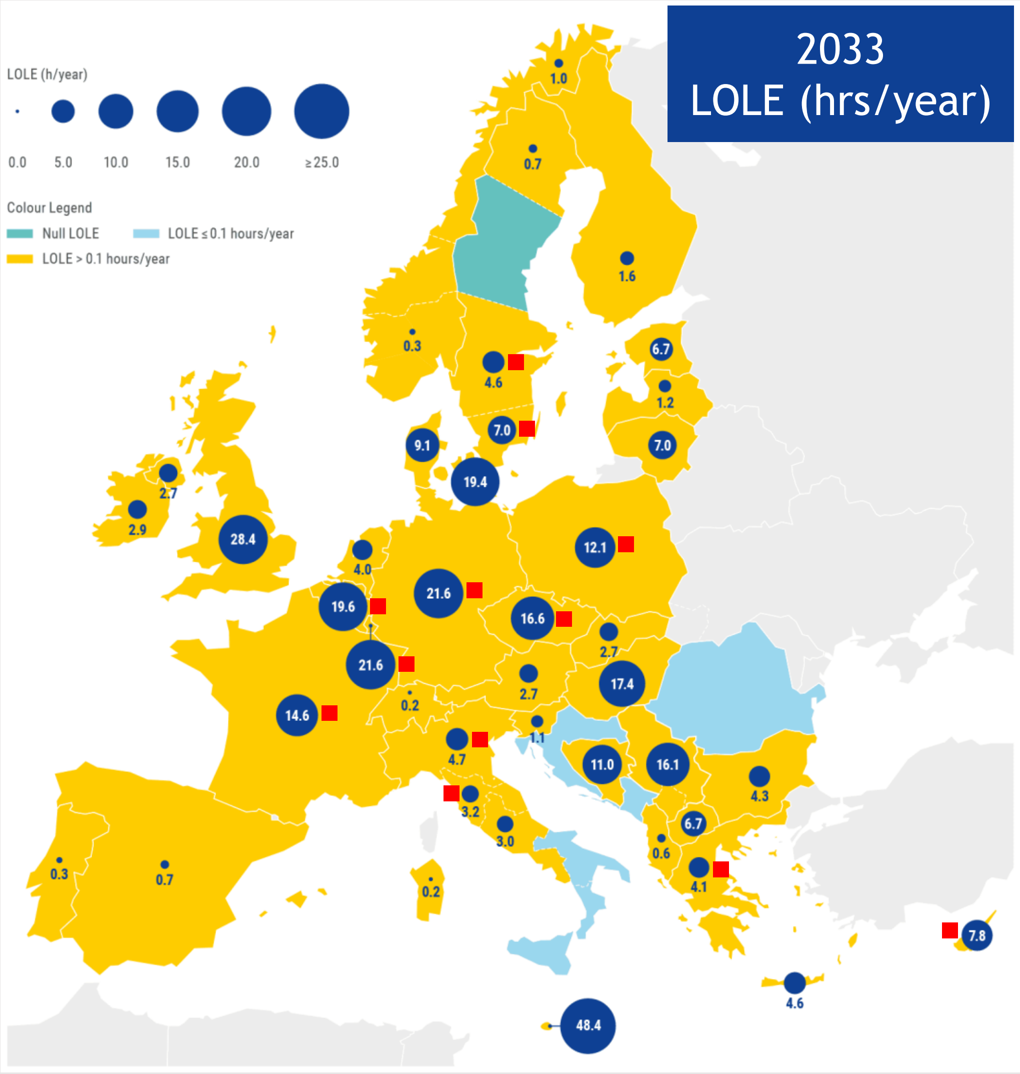


country / bidding zone, where a nationally defined reliability standard is exceeded

Adequacy results – Scenario B / Sensitivity (cont.)

In 2033, LOLE increases significantly in all the geographical perimeter, but mostly in the central and north of Europe.

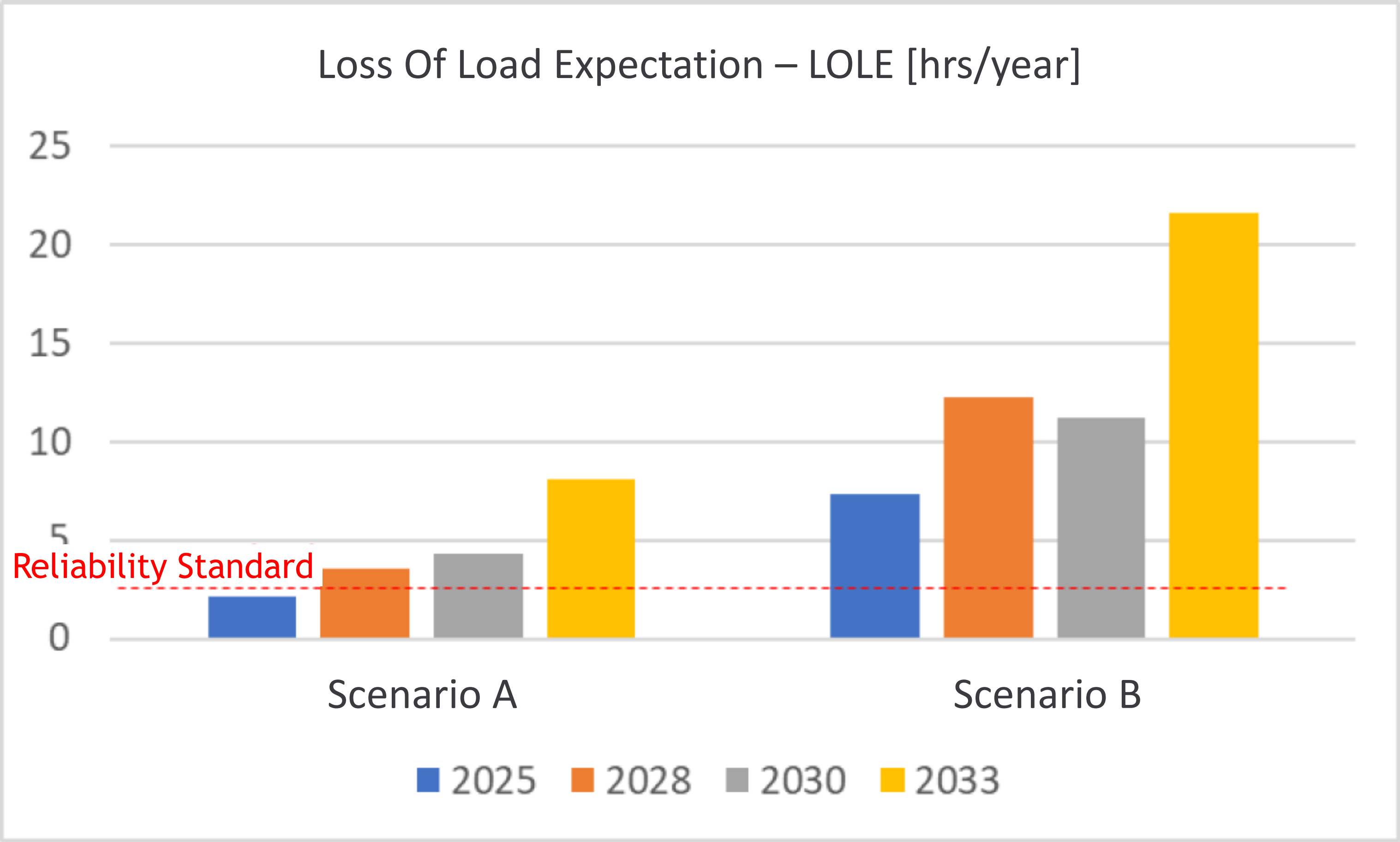




■ country / bidding zone, where a nationally defined reliability standard is exceeded

Adequacy results: Spotlight Germany

Reliability Standard infringend in almost all targets of both scenarios

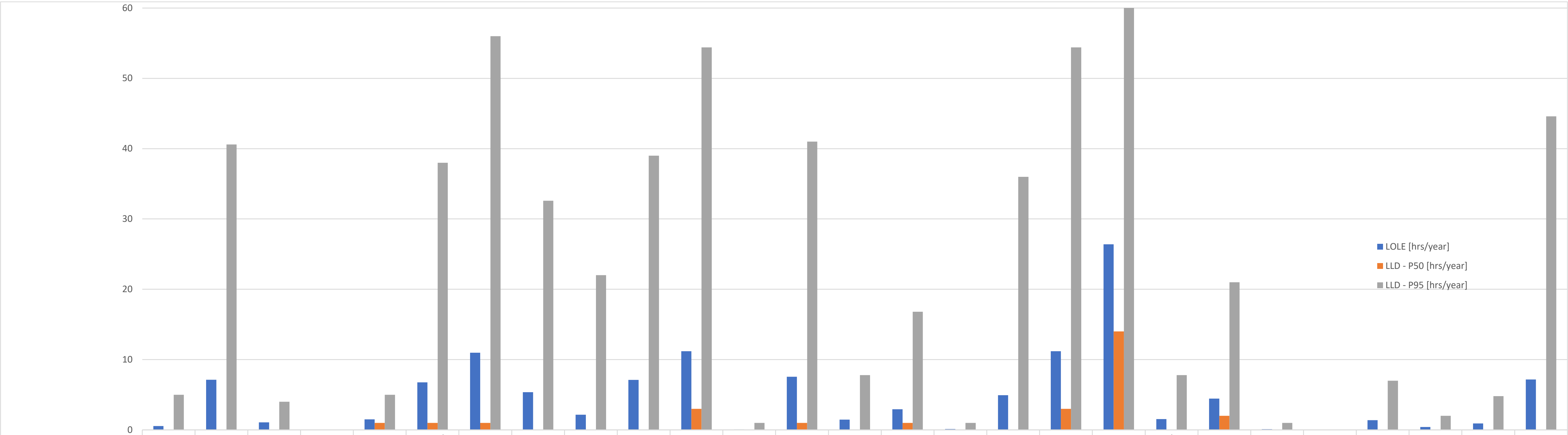


Reliability Standard:

LOLE = 2,77 hrs/year

Adequacy results: LOLE distribution

EU Member States, Target Year 2030, Scenario B – tail events with low probability, but high impact identified



	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxem-burg	Malta	Nether-lands	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden
LOLE [hrs/year]	0,55	7,14	1,08	0,008	1,49	6,77	10,98	5,37	2,15	7,11	11,19	0,07	7,55	1,45	2,93	0,12	4,94	11,19	26,4	1,54	4,46	0,1	0,01	1,39	0,41	0,92	7,16
LLD - P50 [hrs/year]	0	0	0	0	1	1	1	0	0	0	3	0	1	0	1	0	0	3	14	0	2	0	0	0	0	0	0
LLD - P95 [hrs/year]	5	40,6	4	0	5	38	56	32,6	22	39	54,4	1	41	7,8	16,8	1	36	54,4	101	7,8	21	1	0	7	2	4,8	44,6

LOLE [hrs/year]: Loss Of Load Expectation
LLD – P50 [hrs/year]: Loss Of Load Duration – 50th percentile („1-in-2-years event“)
LLD – P95 [hrs/year]: Loss Of Load Duration – 95th percentile („1-in-20-years event“)

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Key takeaways of the ERAA 2023

Continued importance of proactive measures, policy interventions, and strategic planning to ensure energy adequacy in the coming years.

- Fossil-Fuelled Capacity at Risk (Next 5 Years): High volumes are at risk of becoming economically non-viable in the next five years. To avoid adequacy risks, the right incentives/interventions will be necessary.
- Regional Coordination: Adequacy depends on neighboring countries, stressing the importance of regional coordination.
- Flexibility: Growing variability in supply requires the implementation of new flexibility tools that facilitate the management of demand.
- Gas vs. Coal Dynamics: The merit order puts more pressure on gas technologies in 2025, while the trend is inverted from 2028 (bringing gas before coal in the merit order)

Outlook – further development of ERAA

Current Considerations at ENTSO-E

- Is it necessary to monitor the pan-European development of resource adequacy for the next decade with an annual resolution and can this ambition realistically be achieved given the ERAA timeframe and the computational challenges?
- Would a larger number of scenarios and sensitivities for each target year add more value than a larger number of target years?
- Does ERAA already sufficiently investigate the mutual impact of capacity mechanisms in Member States on resource adequacy?
- Do the ERAA scenarios adequately respect national projections, as well as Union-wide and national energy policy targets?
- Is a distinction needed between the objectives of ERAA for shorter-term and longer-term target years?
- Does the economic viability assessment realistically reflect the investors‘ decision making for new builts and retirements of generation and storage capacities, as well as demand flexibilities?

Our values define who we are, what we stand for and how we behave.
We all play a part in bringing them to life.

EXCELLENCE

We deliver to the highest standards. We provide an environment in which people can develop to their full potential.

TRUST

We trust each other, we are transparent and we empower people. We respect diversity.

INTEGRITY

We act in the interest of ENTSO-E

TEAM

We care about people. We work transversal and we support each other. We celebrate success.

FUTURE THINKING

We are a learning organisation. We explore new paths and solutions.

We are ENTSO-E