Integrating Investment and Adequacy in Large-Scale Planning Models: The ERAA Experience

ESIG Spring Technical Workshop, Tucson, 16 - 19 March 2026

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Role of the ERAA*

Assess adequacy risks of the European power system in medium term / coming decade

With focus on pivotal target years: 2028, 2030, 2033, 2035**

Inform decision makers and stakeholders

Reference for Member States to introduce capacity mechanisms

Strengthen Europe's energy transition

Transparent data, complementing other planning studies

* ERAA: **E**uropean **R**esource **A**dequacy **A**ssessment
** Pivotal target years of ERAA 2025

The ERAA framework

TSO Data and NECPs

PEMMDB

Net Generation Capacities

Market Coupling

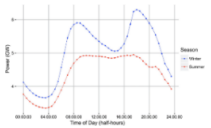
Net Transfer Capacities Flow-Based

PECD

Capacity Factors

Hydro Database

Temperature profiles



Demand

Native demand forecasts

Investor perspective

Economic Viability Assessment (EVA)

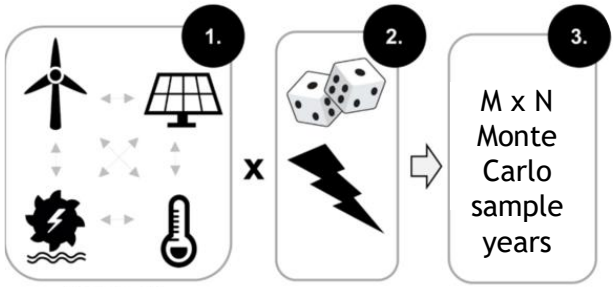
- Stochastic overall costs minimization
- Iterative revenue-based approach

Central Reference Scenario

Includes EVA entry/exit of market capacity

Market perspective

ED Model: Monte Carlo Simulation



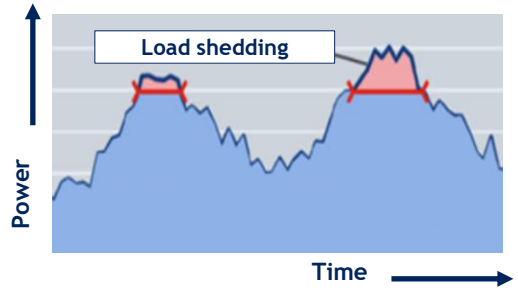
N years of independent climate data

M random draws for unplanned outages

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.

The EU Regulation / ERAA Methodology allow two EVA approaches

REGULATION (EU) 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity

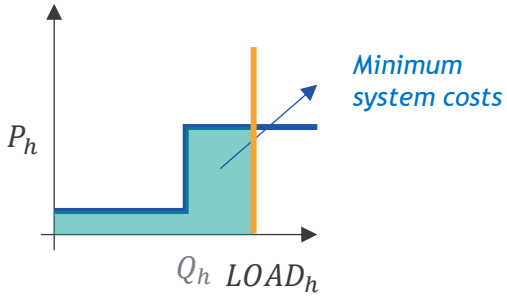
Methodology for the European resource adequacy assessment in accordance with Article 23 of Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, **2 October 2020**

Overall costs minimization approach

applied since ERAA 2021

The installed capacity in power system is optimized to minimize the costs overall system considering:

- Fixed and variable dispatch costs
- Capacity costs (e.g. expansion)
- Load shedding costs



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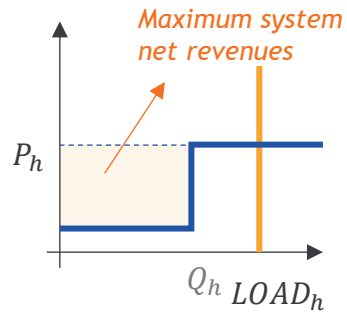
Under **a set of assumptions**:
- *Perfect competition*
- *Perfect foresight*
- *Shedding cost = price cap*

Revenue-based approach

proof-of-concept in ERAA 2025

Investor revenues are:
- Inframarginal rents
- Additional revenue streams

Investor costs are:
- Fixed and variable dispatch costs
- Investment costs



Challenge 1: computational effort

Overall costs minimization approach as an **integrated optimization** solved in a single step

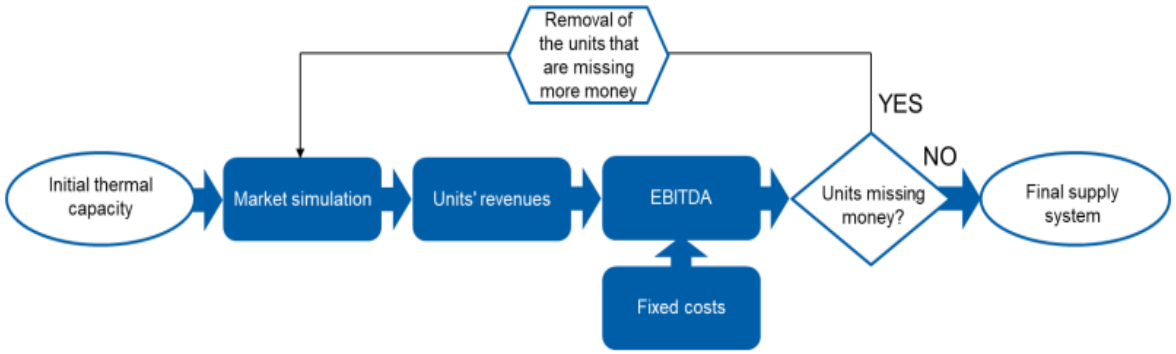
$$\sum_y \sum_g DF_y * (BuildCost_g * GenBuild_{(g,y)})$$

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

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

Concern: Investment modelling must take into account a wide range of uncertainties (e.g. weather scenarios, outages). Single complex stochastic model shows numerical stability challenges; substantial simplifications of power system representation are needed.
Objective: Solution with minimal system costs.

Revenue-based approach as an **iterative loop** solved in a multiple steps



Advantage: Each iterative step is much simpler which allows for considering a wide range of uncertainties in a more detailed economic dispatch model without reaching computational limits.
Objective: Scenario where all units are „in the money“ and no additional expansion is viable.

Challenge 2: investor behavior

The objective of the EVA is to mimic investors‘ behavior as close as possible to reality. But there are numerous challenges:

- „economically imperfect“ decisions motivated by political/societal considerations cannot be captured (e.g. no closure of a site which makes losses in order to not lose scarce workforces / union decisions)
- investments are driven by few scarcity hours with extreme prices while real world investors would not invest multi millions expecting a few “jackpot hours” (“Dunkelflaute” with scarcity prices)

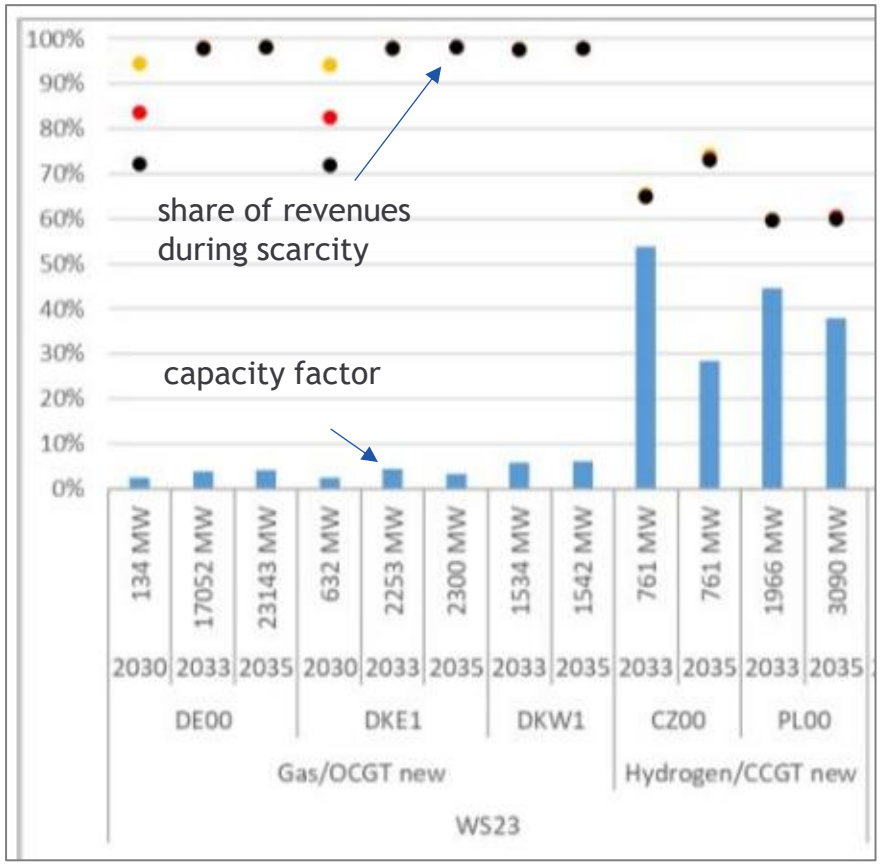
Focus in ERAA 2025

- strategic behavior cannot be captured (e.g. no investment since investors are waiting for possible subsidies from a capacity mechanism instead)
- revenues are not earned in energy-only market only but also other markets (in particular batteries provide balancing services)
- …

➢ *Some of these aspects can be integrated in a simplified way in a model. But others are rather impossible to be captured mathematically.*

Mitigation of extreme price occurrences

Revenue structure – expansion units*

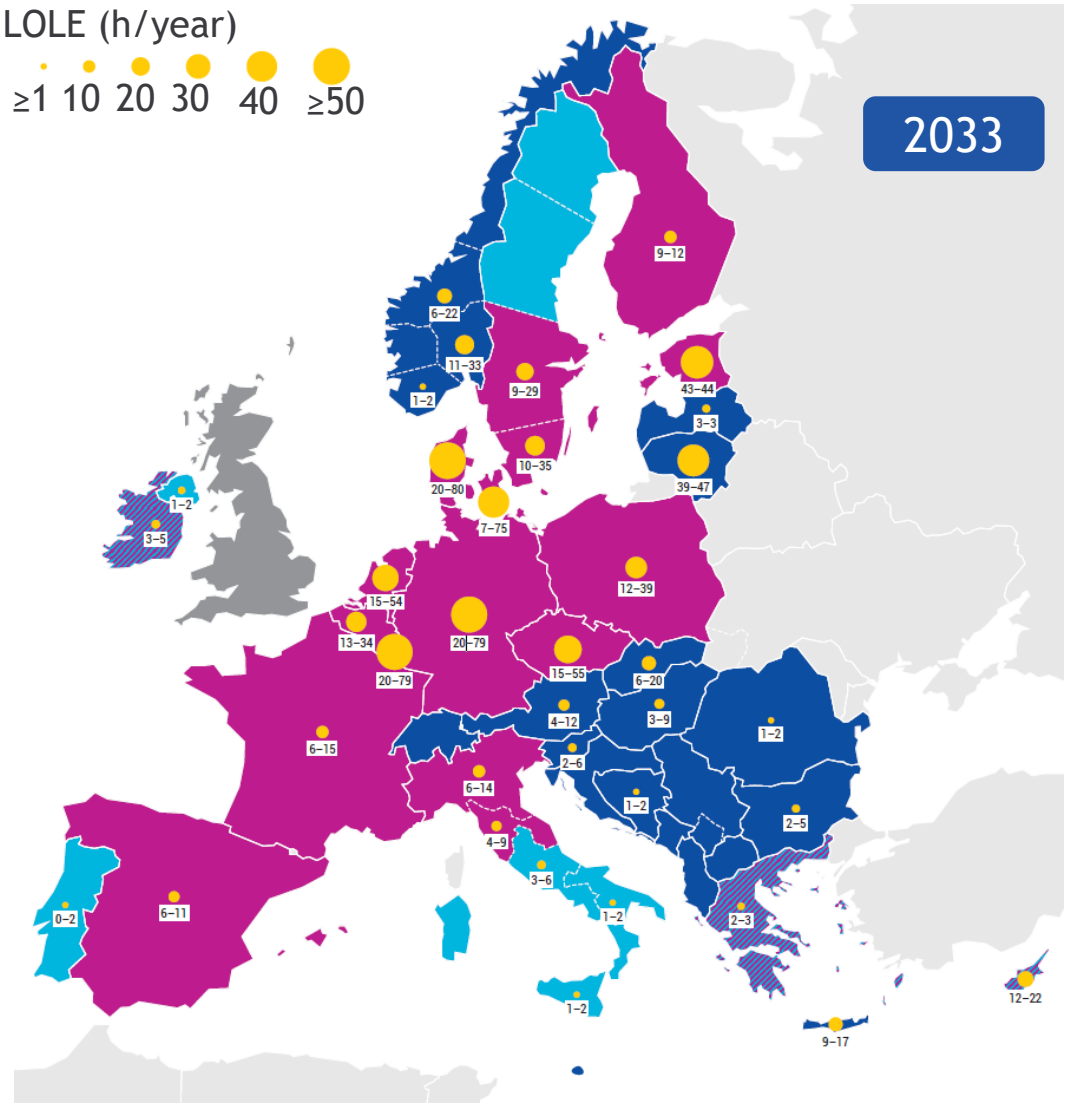


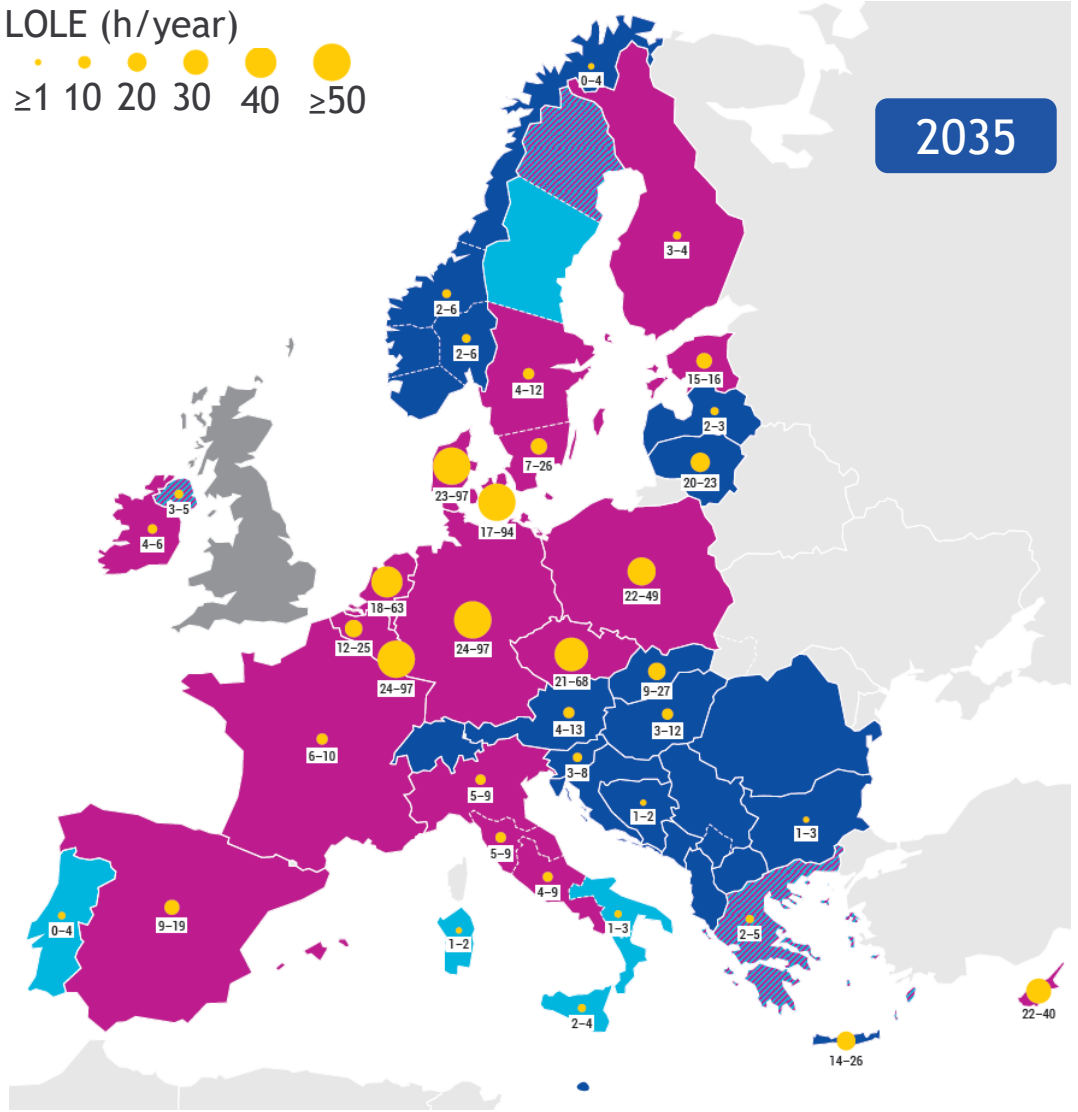
Impact of scarcity prices on investment behavior

- The majority of price occurrences lies in the range between 0 and 200 €/MWh.
- Less than 0.15% of price occurrences above 1,000 €/MWh up to ~7,000 €/MWh (expected market price cap) which are driving investments.
- In ERAA 2025 a revenue cap at 1000 €/MWh was introduced which caps investors‘ revenues in the EVA model.
- This leads to 19 GW (!) / nearly 50% less expansion in Europe compared to the case without revenue cap (25 GW capacity expansion instead of 44 GW in 2035).

* Source: ERAA 2025 – Annex 3

Adequacy results of ERAA 2025





- Within available Reliability Standard
- Exceeds available Reliability Standard
- Reliability Standard within range of risk
- Reliability Standard does not exist
- Results not published

Reliability gap: EVA vs. ED model

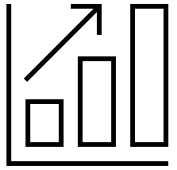
Why are market-driven investments obtained from the EVA by far insufficient to prevent adequacy concerns across Europe?

- In a perfect market, an investment model would converge at: $RS = CONE_{nat} / VoLL$

- The objective of the EVA is to mimic **investors' behavior** and the model converges at:

$$LOLE_{EVA} = CONE_{Eur} / CAP_{rev}$$

- The ED model analyzes the demand balancing capability from a market perspective and converges at:



$$LOLE_{ED} = CONE_{Eur} / CAP_{market}$$

Typically, $VoLL > CAP_{market} > CAP_{rev}$

results in $LOLE_{EVA} > LOLE_{ED} > RS$

➢ *The equilibria of the EVA and ED models diverge and are different from (typically higher than) the reliability standard.*

Legend:

$CONE_{Eur}$:	Cost of new entry harmonized at European level
$CONE_{Nat}$:	Cost of new entry at national level
CAP_{market}:	market price cap
CAP_{rev}:	revenue cap in the EVA model
$LOLE_{ED}$:	„Loss of Load expectation" in the ED model
$LOLE_{EVA}$:	„Loss of Load expectation" in the EVA model
VoLL:	Value of lost load
RS:	Reliability standard

Main takeaways

- An economic viability assessment enables to anticipate major trends in a power system mostly driven by an energy-only market.
- Different methodological approaches are possible, but investment modelling with pan-European coverage remains computationally challenging
- Real world investors‘ behavior can deviate from (perfect) modelling outcomes significantly due to multiple factors (irrational behavior; strategic behavior; policy decisions…).
- Covering a larger range of uncertainties can help to anticipate a more realistic range of future trends but increases modelling complexity even further.
- Market-driven investments obtained from the EVA are by far insufficient to prevent adequacy concerns across Europe.

➢ *Developments of investment modelling in ERAA currently focus on:*

- *price spike considerations*
- *investment strategies (myopic vs. more foresight-oriented decision-making)*

Outlook – further development of ERAA

ERAA methodology to be amended – ACER* decision is expected soon

Current ERAA objective:

- monitoring the development of resource adequacy in Europe
- identification of adequacy concerns for each market zone (with a reliability standard)

Main new feature to come:

- calculation of parameters related to capacity mechanisms including mutual assistance between market zones for countries, which opt for these calculations: derating factors per technology, adequacy gaps, total firm capacity needs

Numerous methodological enhancements:

- scenario assumptions, target years, EVA methodology, revenue streams, investor behavior

* ACER: European Union **A**gency for the **C**ooperation of **E**nergy **R**egulators

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