ERAA 2024 Stakeholder workshop: Methodological Insights

08 August, 2024

Lukas Galdikas, ERAA 2024 Project Manager

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Reliable Sustainable Connected

Housekeeping Rules

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- Ask questions directly through sli.do
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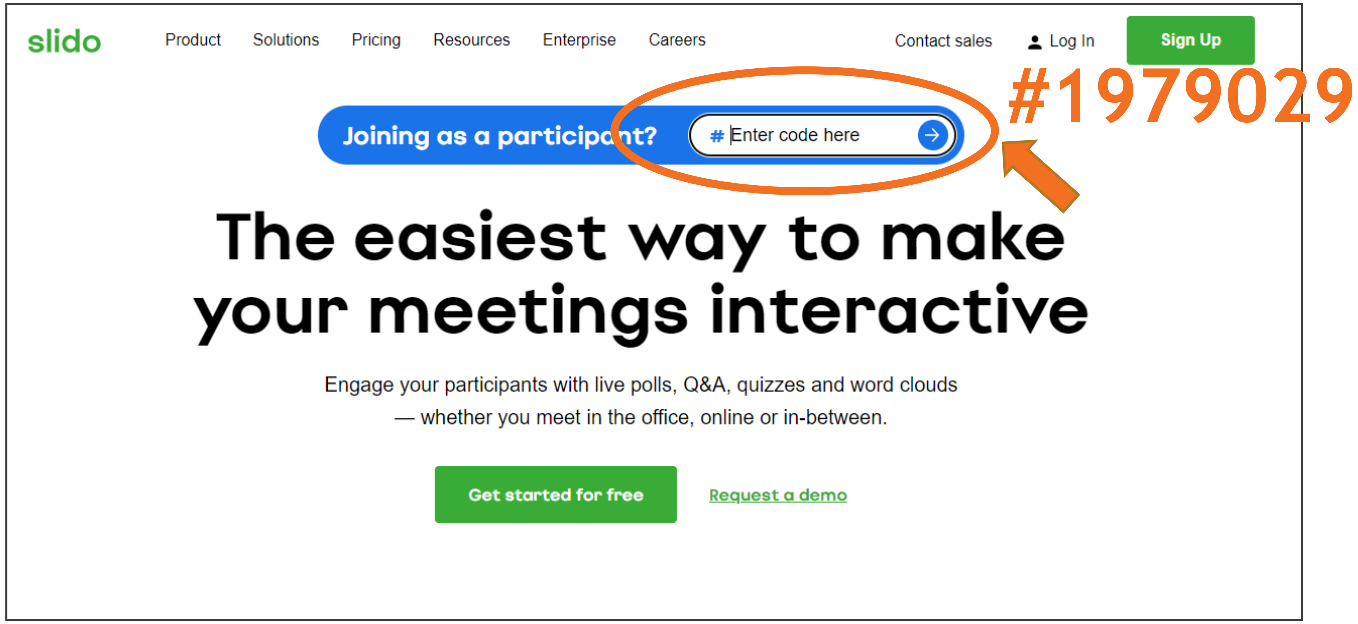
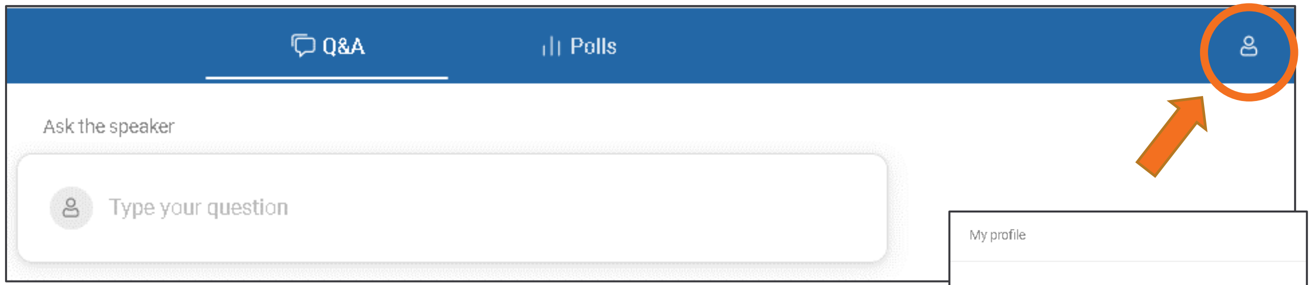
- The moderator will select most relevant questions and ask the speakers to comment
- The teams “chat” and “hand raising” features will not be used.





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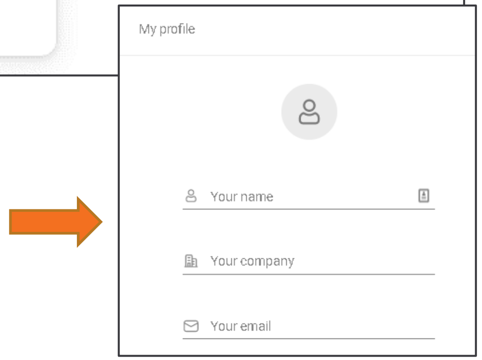

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Agenda

1. **Welcome and scope of webinar**
   Lukas Galdikas (ENTSO-E)
2. **Introduction**
   Javier Quintero Arteche (Red Eléctrica)
3. **ACER's focus on ERAA 2024**
   Daniel Ihasz-Toth (ACER)
4. **ERAA overview & improvements**
   Gregorio Iotti (APG)
5. **Flow-based domain preparations for CORE & Nordics**
   Yaser Tohidi (ENTSO-E)
   Sofie Morud Vågen (Statnett)
6. **Weather scenario selection**
   Laura Torralba Díaz (TransnetBW)
7. **EVA improvements & Hurdle premiums**
   Gregorio Iotti (APG)
8. **Revenue-based EVA**
   Gregorio Iotti (APG)
9. **Q&A**
   Lukas Galdikas (ENTSO-E)
10. **Conclusions and next steps**
    Lukas Galdikas (ENTSO-E)

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Introduction

Javier Quintero Arteche
ERAA Steering Group Member, Red Eléctrica de España

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Background

- ERAA is an ENTSO-E **legal mandate**, which aims to understand how the rapid changes to our energy system will affect security of supply.
- It **supports decision-makers** in ensuring secure, affordable and sustainable energy to citizens and industries.
- It is a **full pan-European monitoring assessment** of power system resource adequacy, based on a state-of-the-art, globally unparalleled **probabilistic analysis** looking up to a decade ahead.
- **ERAA 2024** builds upon the **approved 2023** edition with **continuous improvements** to enhance this key adequacy assessment even further.
- ERAA 2024 aims to be an effective tool to **identify adequacy risks.**
- ERAA is built on **the latest and transparent pan-European reference dataset** emerging from two main domains: data driven by the national and European policies; and cutting-edge common pan-European dataset

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Role of the ERAA

Assess potential adequacy risks of the European power system in medium term

With focus on TY 2026, 2028, 2030, 2035

Inform decision makers and stakeholders

Common basis for MS to introduce capacity mechanisms

Strengthen Europe’s trajectory to net-zero

Strengthen and complement system planning activities

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Continuous improvement

Climate data

- *New Pan-European Climate Database (PECD)*
- *Improved climate changes representation, based on future projections instead of detrended historical data.*

Model

- *Further improve consistency of the Economic Viability Assessment (EVA) and Adequacy models (ED)*
- *Established dedicated development stream, in order to improve both models. EVA focus:*

EVA - COST MINIMISATION	EVA - REVENUE MAXIMISATION
Building on **ERAA 2023** experience	Building on **several TSOs** experiences

Interconnection

- *Flow-Based representation, including Nordic region in Adequacy and Core also in EVA.*
- *Transmission capacity evolution, with updated grid models for FB for each target year.*

Covered in ERAA 2024 Webinar Preliminary Input data - Call for Evidence (link)

Today's Webinar on Methodological Insights

ERAA 2024 Input data stakeholder consultation feedback

Various stakeholders' feedback (link)

	Topics	# Questions
Data validity	• Renewable generation capacities • Thermal generation capacities • Transfer capacities	5
Data description	• Thermal generation capacities • DSR and battery capacities • Transfer capacities	9
Additional data	• Cost of New Entry • FB domain parameters	2
Additional clarification	• Renewable generation capacities • Thermal generation capacities • DSR and battery capacities • Transfer capacities • Demand data	20

Iberdrola
Bundesnetzagentur
CRU An Coimisiún um Rialáil Fóntais Commission for Regulation of Utilities
EDF
smartEn SMART ENERGY EUROPE
ACER

ACER's feedback (link)

Cross-zonal Capacities

- 70% compliance ensured
- EVA-ED model consistency enhanced
- Data validated with some TSOs

Demand-side Response

- Confirmation of the data concerns by most TSOs and some data amendments
- Data validated with some TSOs

Transparency & Stakeholder Engagement

- Recommendation to extend scope of data publication and improve explanation of it

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Extension of the post-consultation data publication scope

The quality of preliminary post consultation dataset release will increase to enhance transparency and stakeholder satisfaction of the ERAA 2024.

Additional items

New data

- New data compared to **ERAA 2023** (e.g. implicit DSR values, economic parameters)
- New data compared to **ERAA 2024 preliminary input data** (e.g. FB domains)

Data documentation

- Data collection guidelines used by TSOs submitting data and further explanations.

Refined or elaborated data

- Non-market resources reported explicitly (separate)
- Consolidated NTC data

Data visualization dashboard

- Improved and implemented in PowerBI
- Additional feature to compare pre- and post-consultation data

ACER

European Union Agency for the Cooperation of Energy Regulators

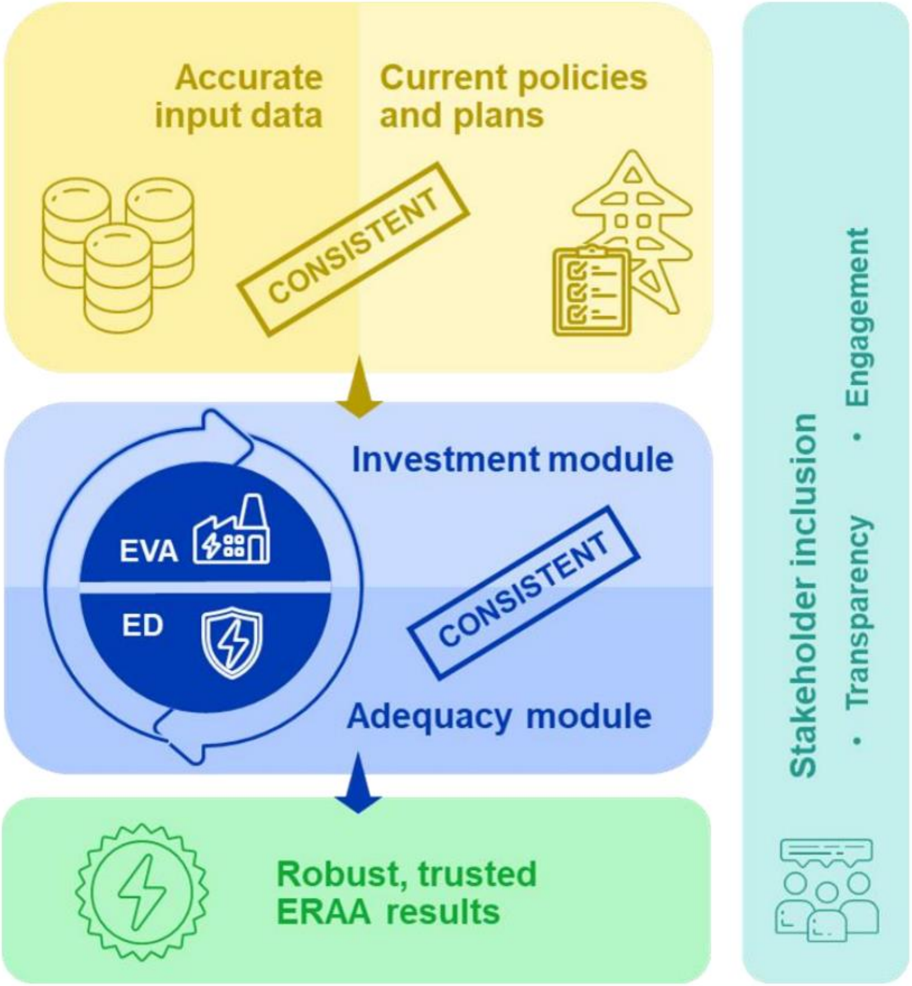
Improving consistency and stakeholder engagement play a key role in 2024

ERAA 2024: Methodological Insights workshop

8 August 2024

ACER European Union Agency for the Cooperation of Energy Regulators

Consistency is central to improving ERAA



- Currently, ERAA builds on two modules:
  - the **investment module** assessing economic viability of resources and
  - the **adequacy module** that calculates the risks for security of supply
- For the ERAA to yield robust results, it is important to use inputs consistently: in both modules.

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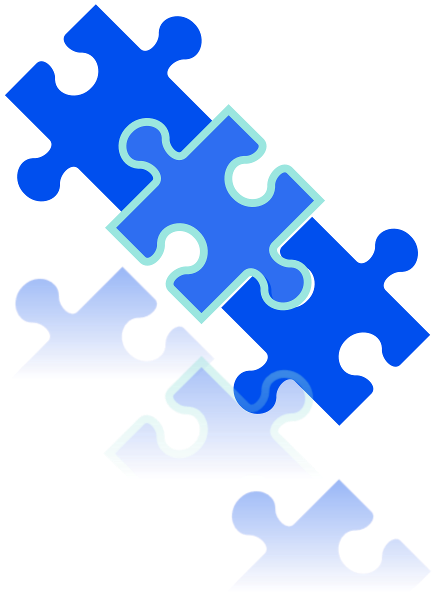
ACER
European Union Agency for the Cooperation of Energy Regulators

Case in point: climatic assumptions

- ACER welcomes the updated climate database in the ERAA inputs. But its implementation into the modelling chain remains challenging.
- The sensitivity in ERAA 2023 demonstrated the important impact of climate assumptions on the end results.
- Weather scenarios must be used consistently in both modules of the ERAA.
- **Challenge**: Currently, the computationally-heavy investment module cannot use as many weather scenarios as the adequacy module.
- **Solution**: Carefully selecting a smaller, but representative subset of weather scenarios for the investment module.
- **Risk**: A non-representative subset would undermine the robustness of the results.

INVESTMENTS MODULE



ADEQUACY MODULE

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European Union Agency for the Cooperation of Energy Regulators

Stakeholders to provide feedback on ERAA input

- After consulting on the national estimates and the climate database in March, ENTSO-E is publishing **a second batch** of input data, establishing a good practice.

- Stakeholders will be able to consult additional information used in the ERAA model.

- Transparency in the ERAA process enhances quality and promotes credibility.

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Thank you.
Any questions?

ACER
European Union Agency for the Cooperation of Energy Regulators

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ERAA overview & improvements

Gregorio Iotti
ERAA Market Study Team Convenor, APG

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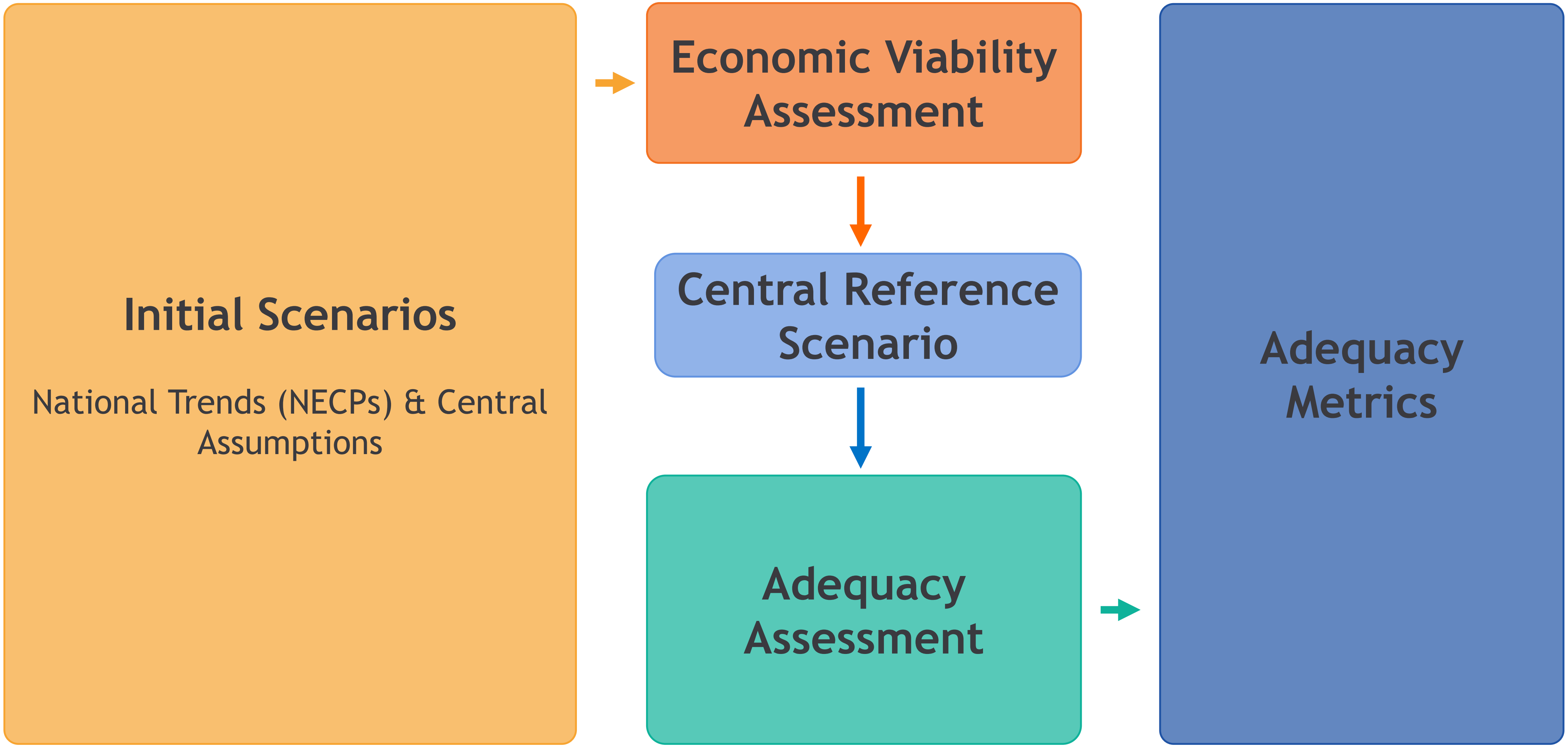
The ERAA – A multi-step process



The Framework of the ERAA

PEMMDB

Net Generation Capacities

Market Coupling

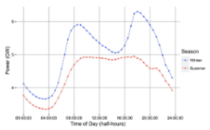
Net Transfer Capacities
Flow-Based

PECD

Capacity Factors

Hydro Database

Temperature profiles



DEMAND

Native demand forecasts

National Trends (NECPs) & Central Assumptions

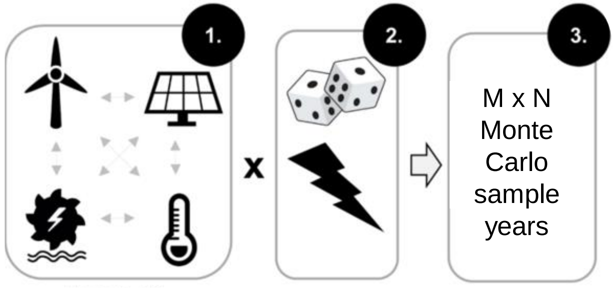
Economic Viability Assessment (EVA)

- Stochastic overall costs minimization
- Iterative revenue-based approach

Central Reference Scenario

- Include EVA entry/exit of market capacity

ED Model: Monte Carlo Simulation



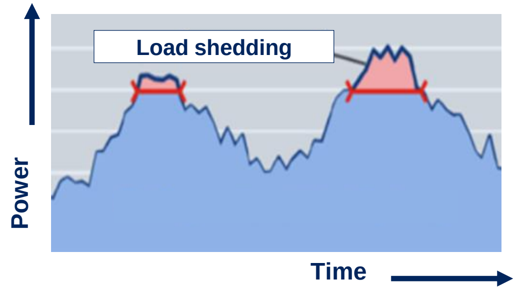
N years of independent climate data

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 [h/yr]:

average number of hours in which the demand exceeds the generation and import capacity in a market area.

EENS = Expected Energy Not Served [GWh/yr]:

average energy not supplied when the demand exceeds the generation and import capacity in a market area.

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The Framework of the ERAA

Zoom in on EVA

Initial Scenarios

National Trends (NECPs) & Central Assumptions

PEMMDB

Net Generation Capacities

Market Coupling

Net Transfer Capacities
Flow-Based

PECD

Capacity Factors

Hydro Database

Temperature profiles

DEMAND

Native demand forecasts

National Trends (NECPs) & Central Assumptions

Economic Viability Assessment (EVA)

- Stochastic overall costs minimization
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Central Reference Scenario

- Include EVA entry/exit of market capacity

Adequacy Assessment

ED Model: Monte Carlo Simulation

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

Adequacy Metrics

adequacy Metrics

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

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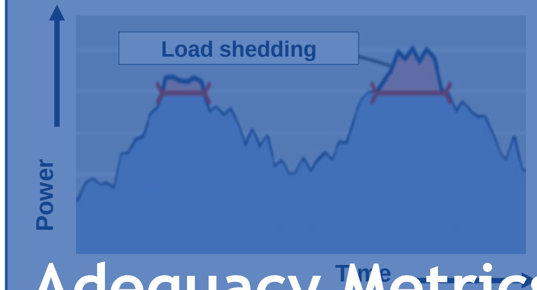

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What is the purpose of the EVA?

Approach

OBJECTIVE

Bring **insights** into the possible **impact** of **uncertainties** on **market-based capacity**

TOOL

A. Use of state-of-the-art **pan-European investment model** through a **multi-year stochastic overall-cost minimization**

B. Development of a **revenue-based EVA with iterative approach**

ANSWER

How likely are generation capacities to be:

- Retired,
- invested in,
- (de)mothballed
- extended in lifetime

Next: Monte Carlo Simulation

Initial Scenarios
National Trends (NECPs) & Central Assumptions

TSO Data and NECP

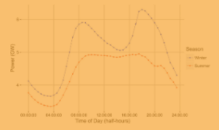
PEMMDB
Net Generation Capacities

Market Coupling
Net Transfer Capacities
Flow-Based

PECD
Capacity Factors

Hydro Database

Temperature profiles



DEMAND
Native demand forecasts

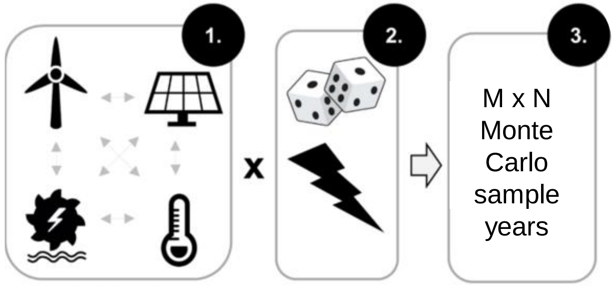
Economic Viability Assessment

Economic Viability Assessment
- Overall costs minimization
- Iterative revenue-based approach

Central Reference Scenario

Central Reference Scenario
- Include EVA entry/exit of market capacity

ED Model: Monte Carlo Simulation



N years of independent climate data

M random draws for unplanned outages

Zoom in on adequacy

Adequacy Metrics

adequacy Metrics

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

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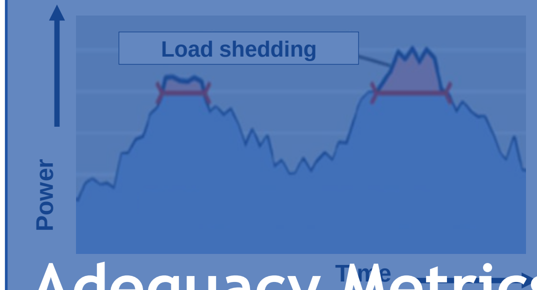

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average number of hours in which the demand exceeds the generation and import capacity in a market area.

EENS = Expected Energy Not Served [GWh/yr]:

average energy not supplied when the demand exceeds the generation and import capacity in a market area.

A grid is adequate when sufficient generation and import capacity allow demand to be met, guaranteeing security of supply

Storage

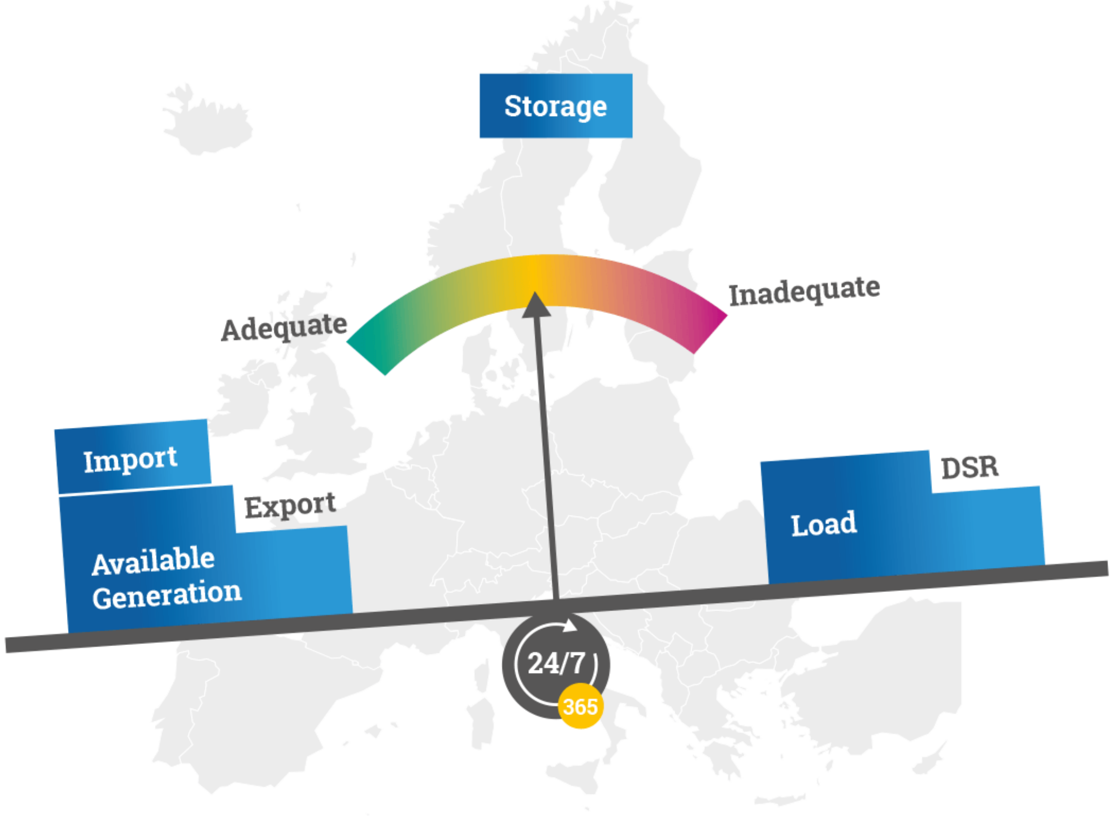
Available Generation | Network Infrastructure | **Demand**

Available Generation =

Deterministic Forecast
- ENTSOs' Scenarios
- Planned Outages

\+

Uncertainty in supply:
- Wind generation
- Solar generation
- Hydro generation
- Forced outages



Demand =

Deterministic Forecast
ENTSOs' Scenarios

\+

Uncertainty in demand:
- Temperature

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The ERAA – Key methodological improvements in the 2024 cycle

Input Data

- New PECD 4.1 Database with projected Weather Scenarios
- ✓ **New FB Domains for CORE**
- ✓ **First ever production of Nordic FB Domains**
- Updated set of CONE data and techno-economic parameters
- ✓ **Improved methodology for Price Cap estimate**

Economic Viability Assessment

- ✓ **Inclusion of FB Market Coupling in EVA model**
- ✓ **New methodology for the selection of representative Weather Scenarios**
- ✓ **New development stream for revenue-based EVA approach**
- ✓ **Improved representation of forced outages on generators**
- ✓ **Hydrogen assessed as expansion technology**

General Modelling Improvements

- ✓ **Pioneering Nordic FB implementation**
- Improved modelling for Rooftop PV & household batteries

✓ ***Today's agenda***

Flow-based domain preparations for CORE & Nordics

Yaser Tohidi
Modelling specialist, ENTSO-E

Sofie Morud Vågen
Market Modelling Analyst, Statnett

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Background

Why do we need to consider Flow-based market coupling in the ERAA?

CAUSE

Actual or expected **market arrangements** compliant with **CACM regulation**

Better utilization of European network

CONTEXT

Core: go-live in May 2024, extension in granularity (IDA) and regionally (merge of Italy North)

Nordic: FB go-live in 2024-2025

GOAL

FB for **Core**
FB for **Nordic**

APPROACH

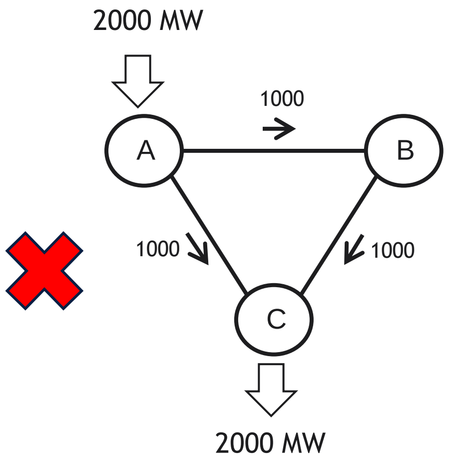
Flow based domains computed from the **network models** independently for Core and Nordic

What is Flow-based capacity allocation?

NTC vs. FB

NTC

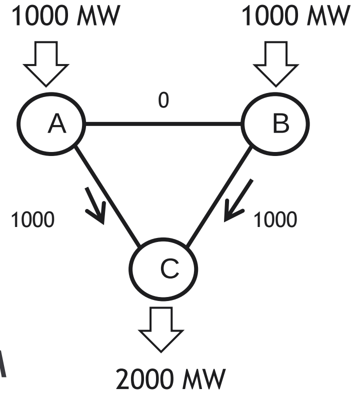
NTC approach consists of **import and export limits** for each border on which the TSOs agree.



Line	Max exchange
A -> B	750 MW
B -> C	750 MW
A -> C	750 MW

FB

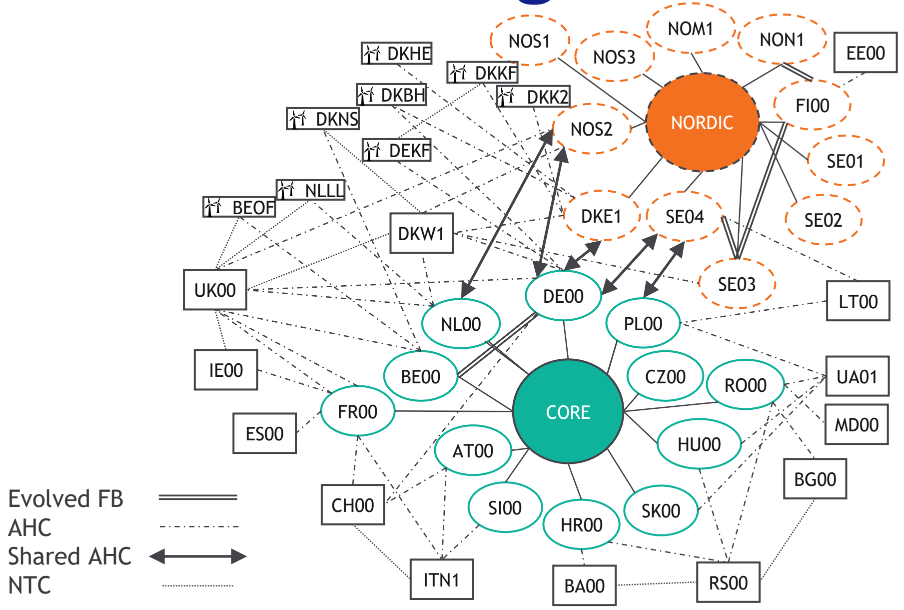
FB approach leaves it to the **market** to consider the interdependencies between the flows crossing the different borders in order to **enlarge the achievable net positions.**



	Line	Max exchange (RAM)	Input zone A (PTDF)	Input zone B (PTDF)	Input zone C (PTDF)
CNEC	A -> B	1000 MW	33 %	- 33 %	0
CNEC	B -> C	1000 MW	33 %	67 %	0
CNEC	A -> C	1000 MW	67 %	33 %	0

PTDF: Power Transfer Distribution Factor
RAM: Remaining Available Margin
CNEC: Critical Network Elements and Contingencies

FB Improvements in the complex Core and Nordic Capacity calculation regions



For the first time

1. **Core Flow-based domains** have been calculated **for every TYs individually.**
2. **Nordic Flow-based** domains were prepared **for the pan-European study for the first time.**
3. **EVA will accommodate simplified Core FB** domains to enhance consistency with adequacy models.
4. Increased complexity of **two flow-based regions interconnected in the adequacy model.**

CORE CCR		
Study	ERAA 2023	➡ ERAA 2024
ADEQUACY	FB TY 2025 + expansion* 2 Winter + 2 Summer	FB all TYs individually 3 Winter + 3 Summer
EVA	NTC + NPCs	FB all TYs 1 Winter + 1 Summer

Nordic CCR		
Study	ERAA 2023	➡ ERAA 2024
ADEQUACY	NTC	FB all TYs RAMs in 3-hour steps
EVA	NTC	NTC + NPCs

**Additional RAM needed to accommodate NTCs*

Core FB domain calculation process

1. Nodal Model
2. FB parameters of typical domains
3. Random forest and allocation

Core - FB calculation process

1

Step 1. Nodal Model

Dispatch set-points

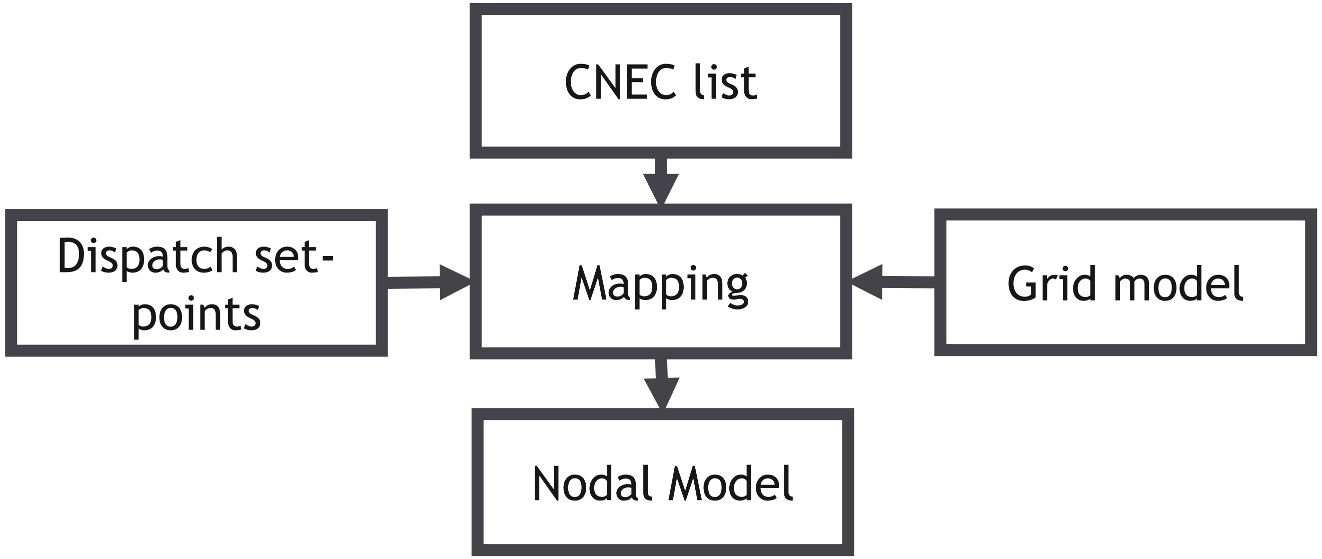
ERAA 2023 results for CYs 1988 (high RES), 2010 (high residual demand) and 2014 (low demand)
- TY 2025 (proxy for 2026)
- TY 2028
- TY 2030
- TY 2033 (proxy for 2035)

Grid models of TYNDP 2022

Adjusted for ERAA 2024 target years
CNEC list collected from TSOs

Mapping

Generation → based on study zone and technology
Demand → based on study zone and actual load
External exchanges → based on the transmission line capacity



Core - FB calculation process

2

Step 2. FB parameters of typical domains

CLUSTERING

Clustering done (K-Medoids) based on flows over CNEs

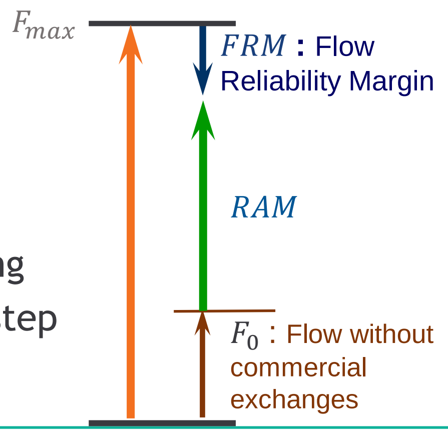
3 winter + 3 summer

1 winter + 1 summer (back-up EVA)

RAM

FRM based on TSOs' feedback

Adjustment for minimum RAM (ARM) according to MACZT70% after applying remedial action optimisation (RAO) step



GSK STRATEGY

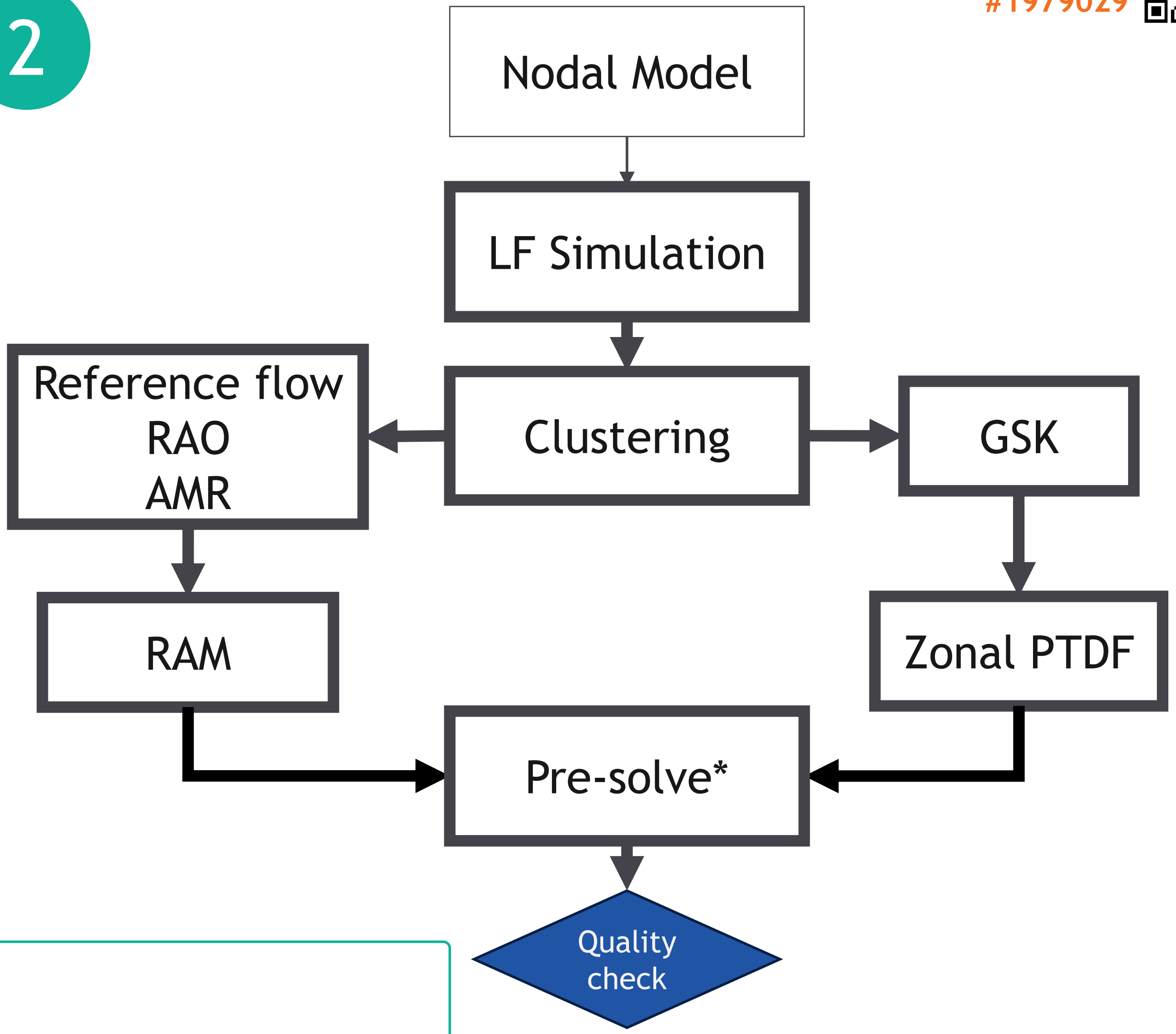
Proportional to Pmax of dispatchable units

Nuclear units excluded in smaller study zones (SI00, SK00, RO00, CZ00)

$$p_{\mathrm{L}} = PTDF_{\mathrm{N}} \cdot p_{\mathrm{N}}$$

$$PTDF_{Z\ line\ a}^{\ zone\ A} = \sum_{k=1}^{k=n} PTDF_{N\ line\ a}^{\ node\ k} \cdot GSK_{\ node\ k}^{\ zone\ A}$$

$$p_{\mathrm{L}} = PTDF_{Z} \cdot p_{\mathrm{Z}}$$



* Pre-solve step is a process aiming at removing all CNECs which are not limiting for the flow-based domain.

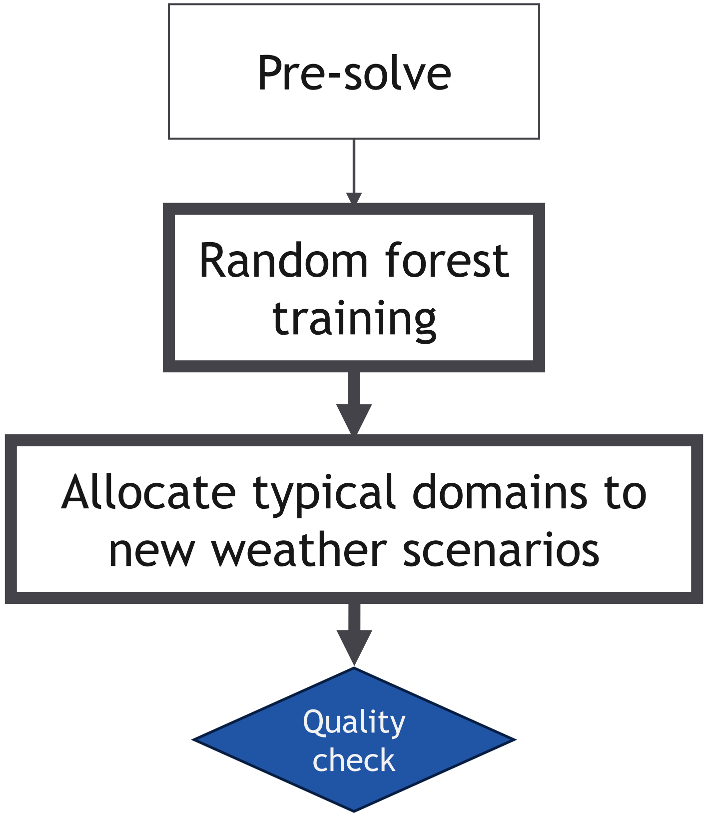
Core - FB calculation process

3

Step 3. Random forest and allocation

Random forest model is trained by the level of wind, solar, load and hydro inflows in the region for each cluster.

The same parameters from the new weather scenarios are used to find the allocations of clusters.



Nordics Calculation process

1. First delivery of FB domains
2. Simulation assumptions
3. FB calculation process

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Nordic – First delivery of FB domains

1

MARKET MODEL

Market model Samnett is used for FB domain creation

- Integrated grid model with nodal connections
- Already creates FB domains
- Used in market analysis by Statnett and SvK

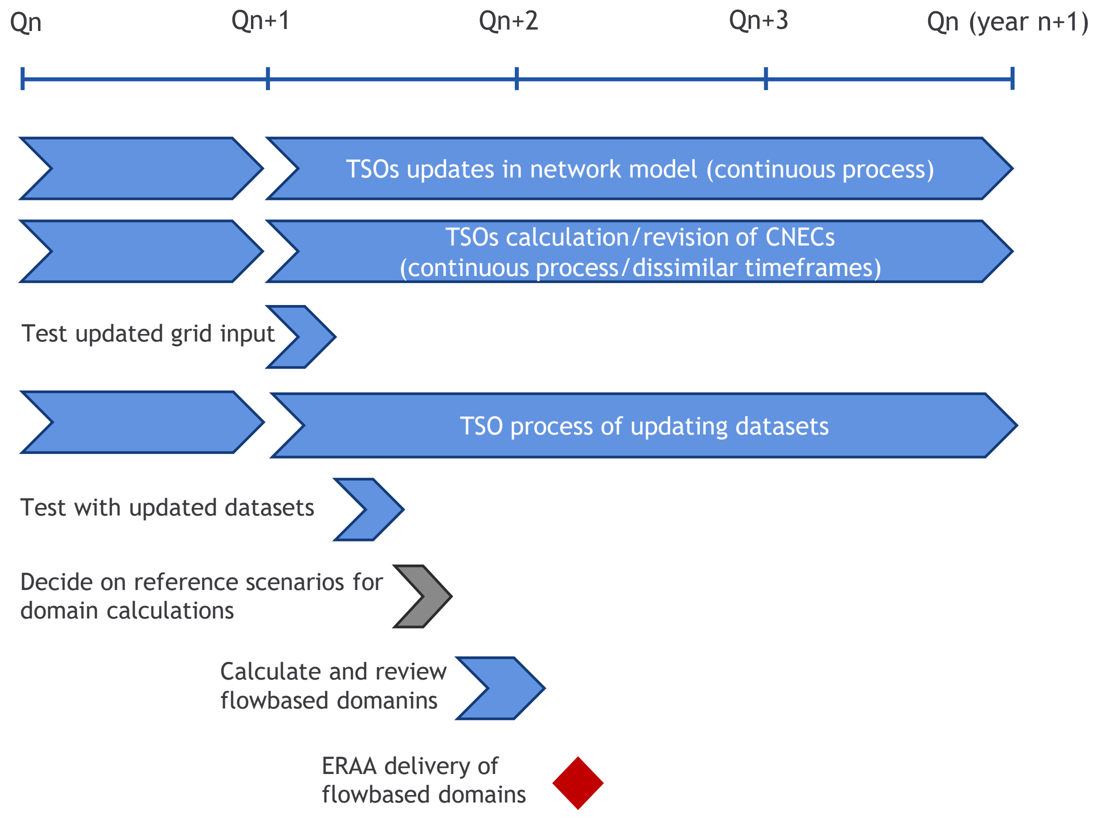
UPDATING THE GRID MODEL

- Grid model based on individual TSO input

CNEC SELECTION

- CNECs provided by the TSOs, and the network model, are crucial for getting representative domains
- Main focus on CNECs on the borders. In Norway and Sweden we have included some internal CNECs as their loading influence cross-border capacity

Yearly Nordic process:



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Nordic – Simulation assumptions

2

RAM VALUES

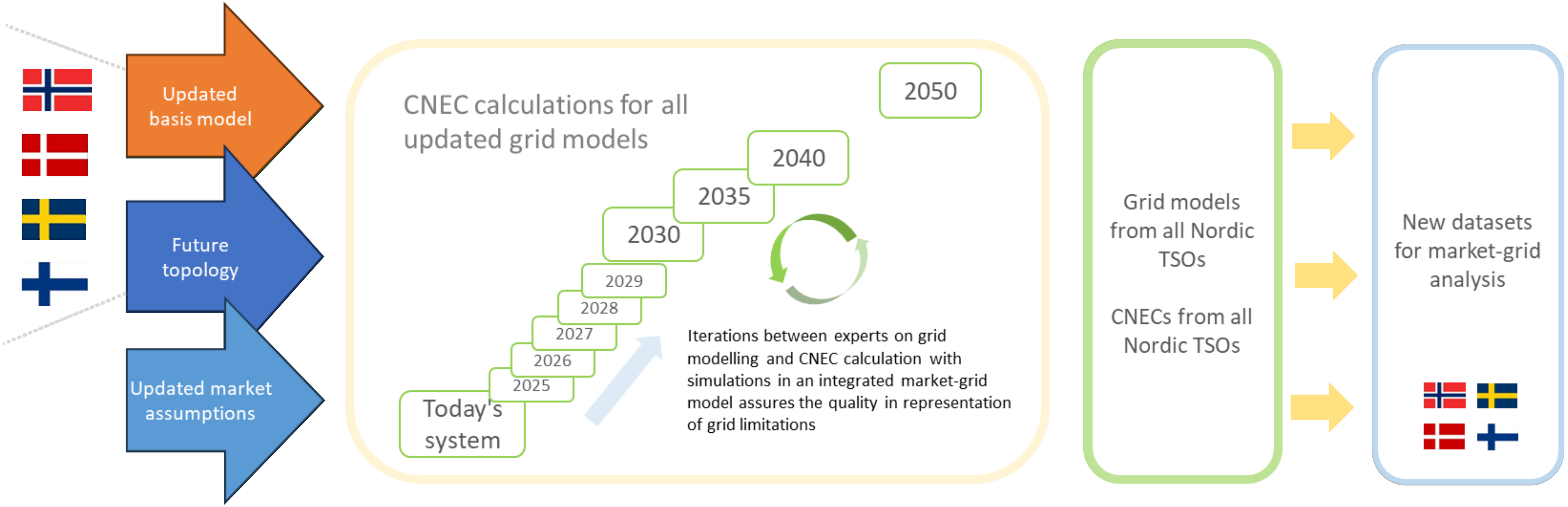
- Calculated for each tree hour step in the simulation
- RAMs calculated for all CNECs
- Create PTDFs for 2 representative years (2025 and 2030) – with small adjustments to represent TY 2026, 2028 and 2035
- We used scenarios from the most recent long- and short-term analysis performed by Statnett

CLIMATE YEAR

- Results for one representative CY
- 1999 – average CY
- Also representative in terms of consumption in the Nordics

Parameter	Nordic assumption
Time resolution	1 h (3 hour resolution in the simulations)
CCR	Nordics
Market model	Samnett - Statnett LMA
Grid model	TSO-developed Nordic grid model based on TYNDP (2025 and 2030). Updated Sweden and Norway. Model for Denmark and Finland is older. Tie line updates are according to TYNDP.
CNECs	All cross-border **and relevant internal lines** communicated by TSOs
minMACZT	MinRAM = 20%
Number of representative domains	1 PTDF * 2912 RAM domains per TY
GSK strategy	Flat

Nordic – FB calculation process



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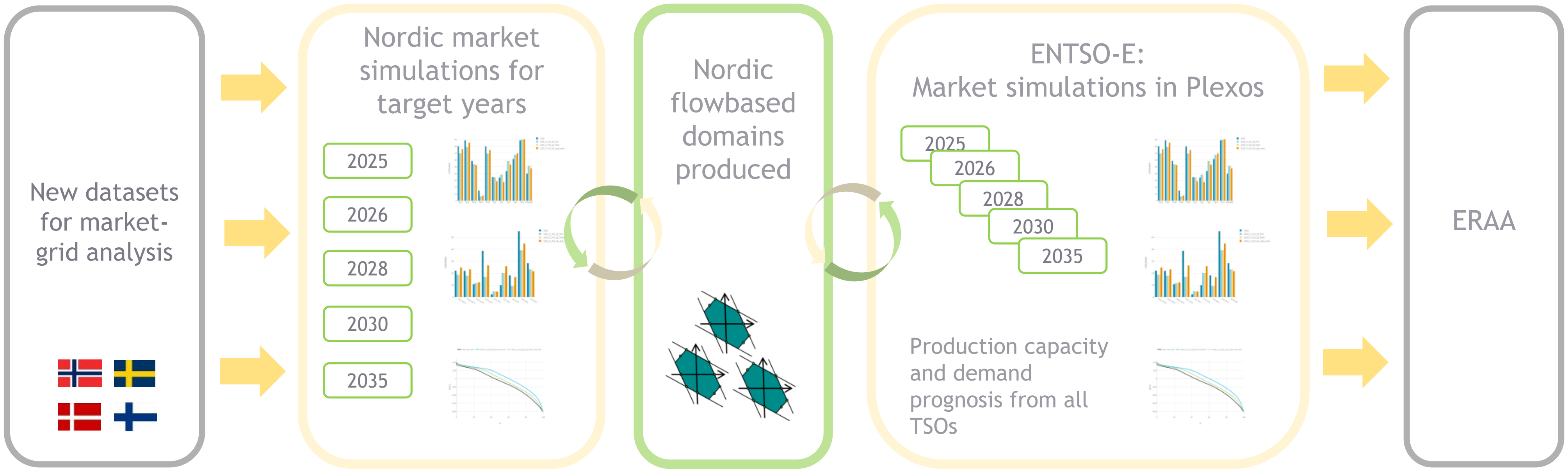
Nordic – FB calculation process



Weather Scenario Selection

Laura Torralba Díaz
Market Modelling Analyst, TransnetBW

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Background

Why do we need a new methodology to select a subset of weather scenarios for the EVA cost minimization approach?

CAUSE

The EVA cost minimization stochastic approach requires **model size simplifications**

CONTEXT

Previous ERAA 2023 methodology cannot be used

Fully new PECD with climate projections in ERAA 2024

GOAL

Selection of a **representative subset of 3 weather scenarios** (climate projections)

APPROACH

Input-based or **impact**-based

Background

Why are we developing two approaches for the weather scenario selection in EVA?

INPUT-BASED

Residual load calculated from PECD+PEMMDB data as key indicator of the system state

Selection of a representative subset based on mean, standard deviation and peak clustered using a **k-medoids** score methodology

- **Independent of ED runs** and easier to accommodate in the timeline
- **Tested methodology** and **easy to replicate**
- Representativeness of the subset adjusted with **clustering-based weights**

IMPACT-BASED

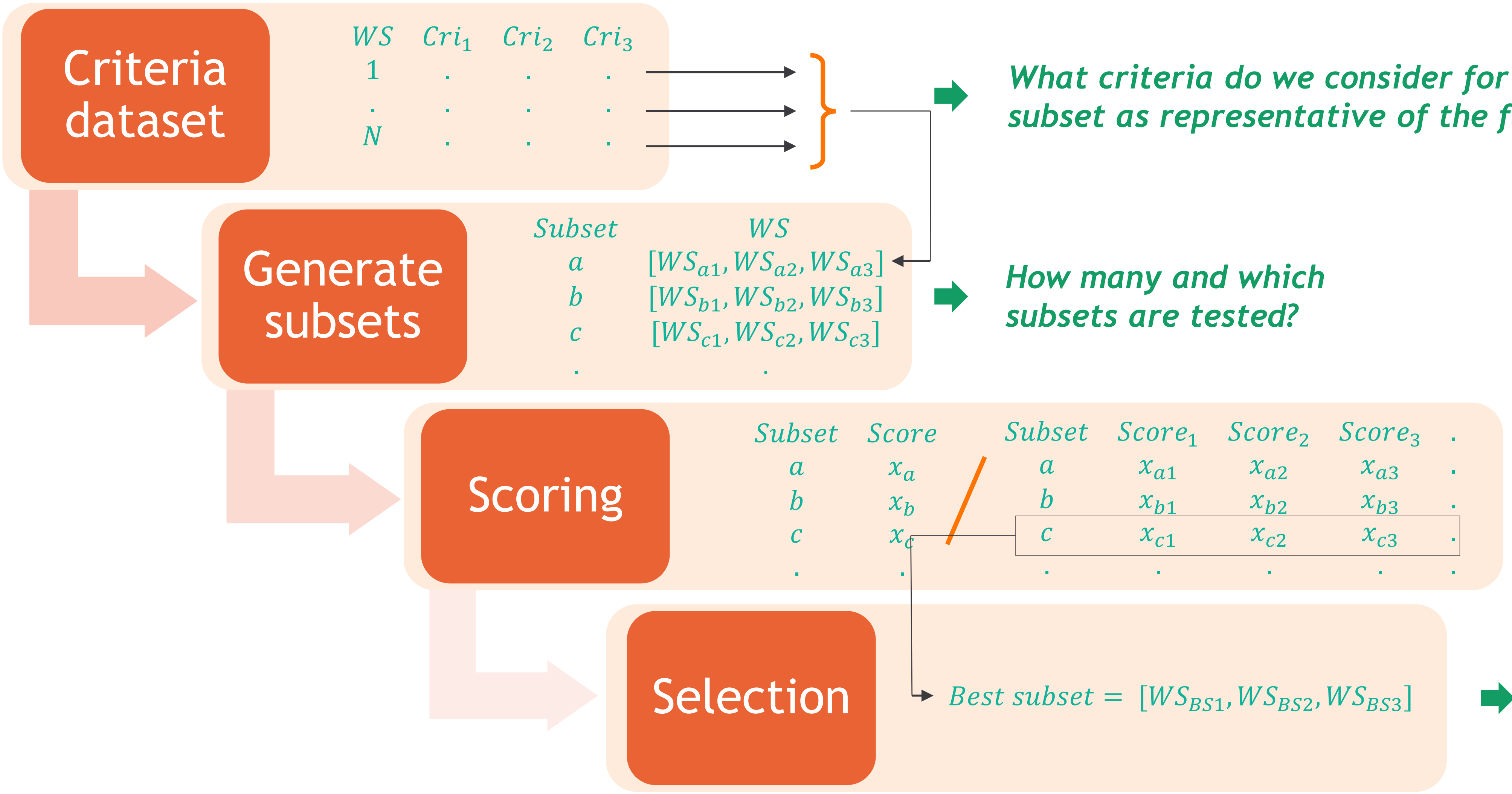
Economic & reliability results from the initial ED run used as key criteria

Selection of a representative subset based on **minimum absolute error** or **Wasserstein metric**

- **Dependent on ED runs** and challenging to accommodate in the timeline
- **Multiple criteria** available
- **Direct assessment of revenues** is now considered
- **ENTSO-E and ACER’s recommendation**

Impact-based Methodology

The selection methodology must answer several key questions



What criteria do we consider for qualifying a subset as representative of the full set?

How many and which subsets are tested?

How do we assess if a subset is more representative than another?

Which is the most suitable subset?

Impact-based Methodology

Criteria dataset

WS	Cri_1 BZ_1	Cri_1 BZ_2	.	Cri_2 BZ_1	Cri_2 BZ_2	.
WS_1	x	x	.	x	x	.
WS_2	x	x	.	x	x	.
.	.	.	.	.	.	.
WS_{36}	x	x	.	x	x	.

- Dataset = model outputs

single value for each weather scenario, criteria and bidding zone

ENTSO-E's recommendation

1) **Set of economic & reliability criteria:**
   - **Average prices**
   - **Price spikes** *(N. hours at price > 90% price cap)*
   - **LOLE**
   - **ENS**

2) **Net Revenues (actual):**
   - **actual unit net revenues** extracted from the model results and aggregated

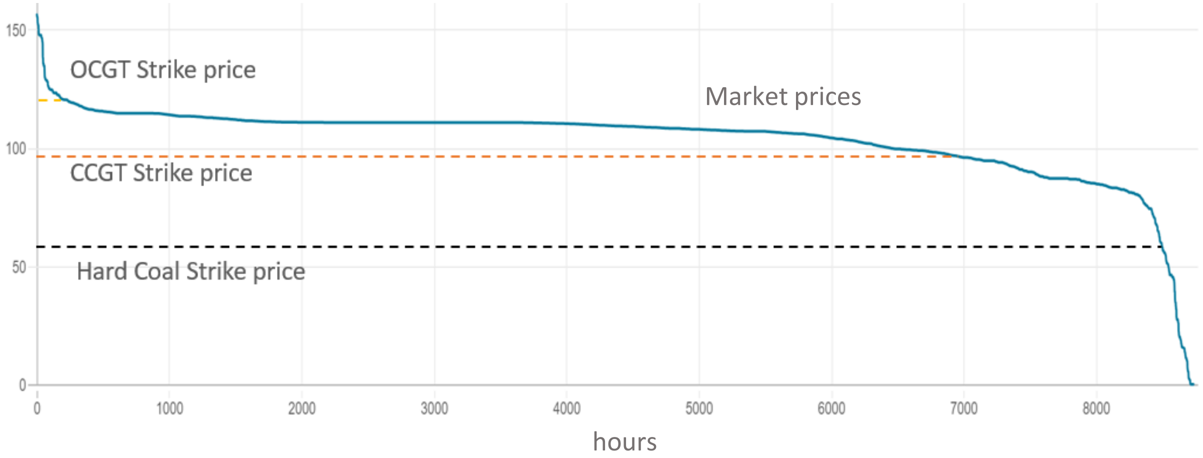
     = *(Electricity price x Generation) - (Generation & Emissions cost)*

3) **Net Revenues (proxy):**
   - **proxy of net marginal revenues per MW** for several thermal technologies

Impact-based Methodology

Criteria dataset

Deep dive on proxy revenues



The analysis of the hourly marginal prices distribution against the generation marginal cost of technologies, allows to estimate the potential revenues of a marginal MW of an (ideal) generator added / kept in the system:

$$R_{proxy,tech} = \sum_{h} \max(\underbrace{\lambda_h}_{\substack{marginal\\ system\ cost}} - \underbrace{SRMC_{tech}}_{\substack{short\ range\\ marginal\ cost}}, 0)$$

Impact-based Methodology

Scoring metrics & Selection

Minimum absolute error

- For each subset and bidding zone, we calculate the absolute error:

$$s_{i,bz} = \sum_k \left| \frac{\mu_k^{i,bz}}{\mu_k^{bz}} - 1 \right| + \left| \frac{\sigma_k^{i,bz}}{\sigma_k^{bz}} - 1 \right|$$

σ: standard deviation μ: mean bz: bidding zone
i: subset k: criterion

→ The absolute errors of the bidding zones are weighted summed

Subset	*Score*
a	s_a
b	s_b
c	s_c
.	.
M	s_M

→ Best Score $= \min(s_a, s_b, s_c, \dots s_M)$

Best subset is the one that minimizes the absolute error

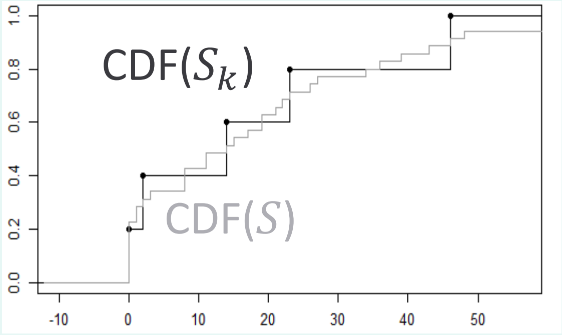
Wasserstein metric

ENTSO-E's recommendation

For each subset, criteria and bidding zone, we build *cumulative distribution functions* (CDF)

Wasserstein distance between set S and subset S_k:

$$W(S, S_k) = \int |CDF(S) - CDF(S_k)|$$

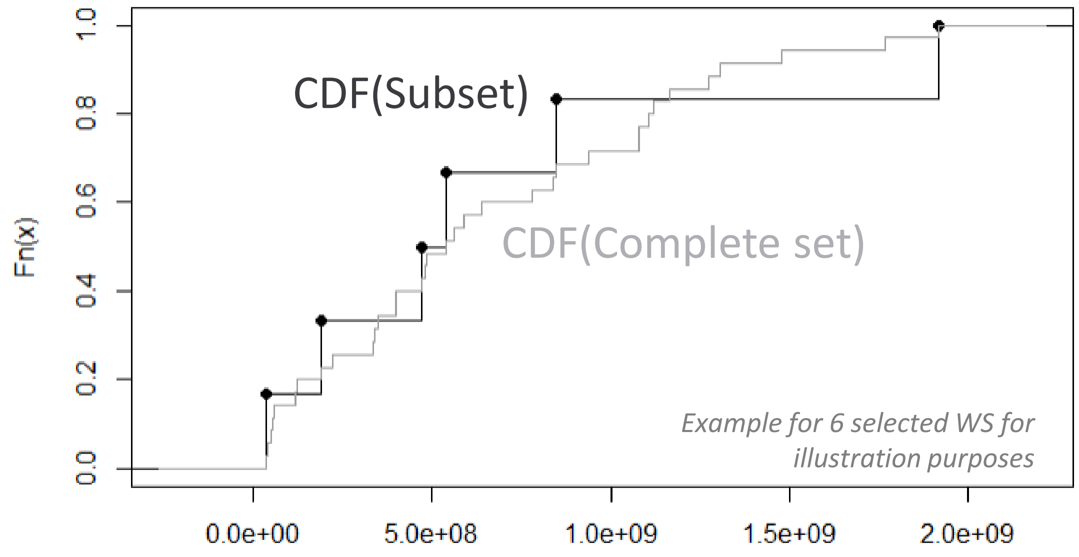


→ **Best subset is the one that minimizes the sum of Wasserstein distances, i.e., the sum of the absolute areas between the two curves (set and subset)**

Impact-based Methodology

Scoring metric

Deep dive on the Wasserstein metric



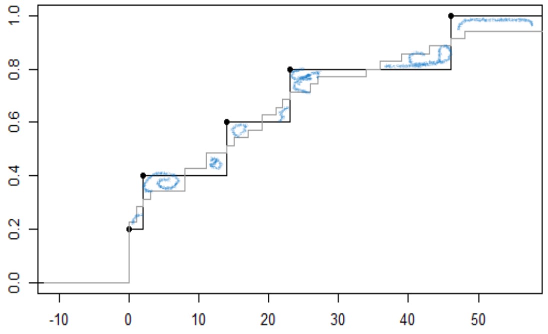
Wasserstein metric helps us to compare two cumulative distributions by calculating the area between the two functions via integrals:

$$W(Set, Subset) = \int |CDF(Set)(x) - CDF(Subset)(x)|dx$$

- A standardization is required if the criteria have different ranges of values:

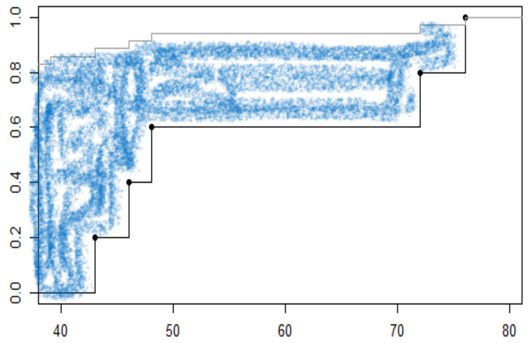
$$Z = \frac{X - \mu}{\sigma}$$

- If a standardization is applied, the Wasserstein distances of the bidding zones are weighted summed



Good candidate

Bad candidate



Outcomes of preliminary calculations

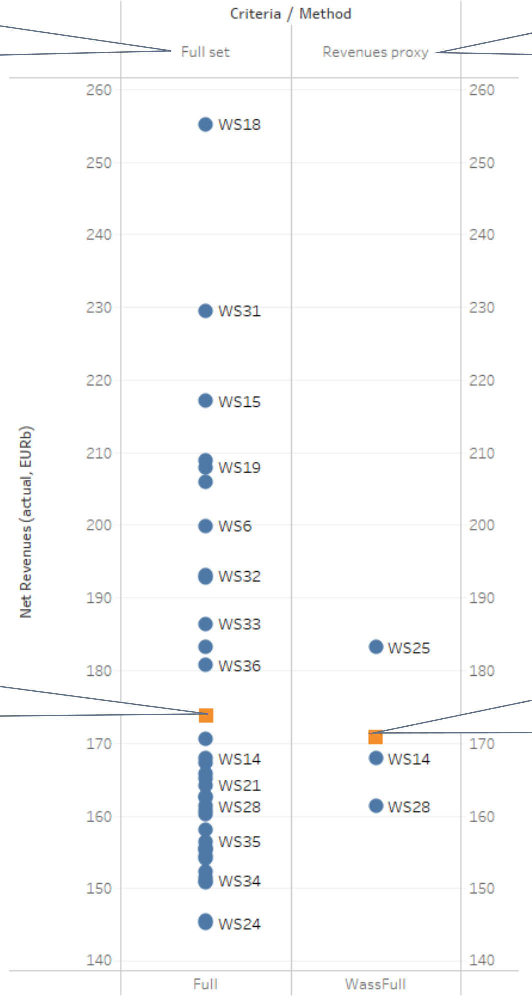
Following current ENTSO-E's recommendations

- WS selection based on:
  - Approach: **Impact-based**
  - Criteria dataset: **Net revenues (proxy)**
  - Scoring metric: **Wasserstein**
  - Weighting of bidding zones: **Based on residual load**

Preliminary outcomes: WS selection approach is being refined and validated

Sum of net revenues for all weather scenarios (TY 2030)

Sum of net revenues for selected weather scenarios (TY 2030)



Orange square: Average of the set of all weather scenarios

Orange square: Average of the subset of selected weather scenarios

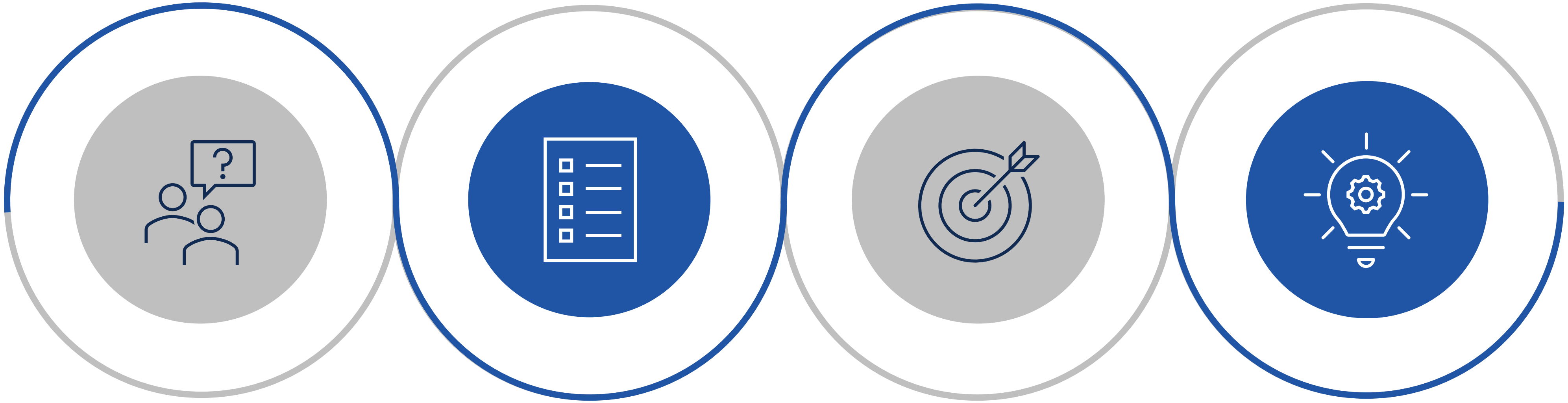
Selected weather scenarios: **WS14, WS25 and WS28**

EVA improvements & Hurdle premiums

Gregorio Iotti
ERAA Market Study Team Convenor, APG

Background

What additional improvements we achieved in EVA and why we need them?



CAUSE

Due to high complexity, the overall costs EVA model is subject to additional simplifications compared to ED models

CONTEXT

Achieving a higher consistency between ED & EVA is of key importance as highlighted by ACER

GOAL

Reduce the gap between EVA & ED methodology by acting directly at the root elements in the models

APPROACH

Aside from FB & WS selection, improvements secured for FO modelling, price cap and expansion candidates

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Additional EVA improvements

Several improvements towards robustness and consistency

	1 Maximum Price Cap	2 Expansion Candidates	3 Forced Outage Modelling
ERAA 2023	Exogenous calculation based on ERAA 2022 results from one single target year	Natural gas blend CCGT and OCGT, grid-scale batteries and explicit DSR units	Average derating of net capacity by forced outage rate
ERAA 2024	Exogenous calculation based on ERAA 2023 results from all target years	Hydrogen-fired CCGT and OCGT units assessed as additional expansion candidates*	Transferring a representative outage sample from ED to EVA model
MOTIVATION	Improve robustness of price cap estimates with expected evolution of the system	More comprehensive EVA Overcome expansion limits due to specific gas policies	Improve consistency between EVA and ED

* Screening curves show that gas-blend technologies are more competitive than hydrogen within the scenario of ERAA 2024

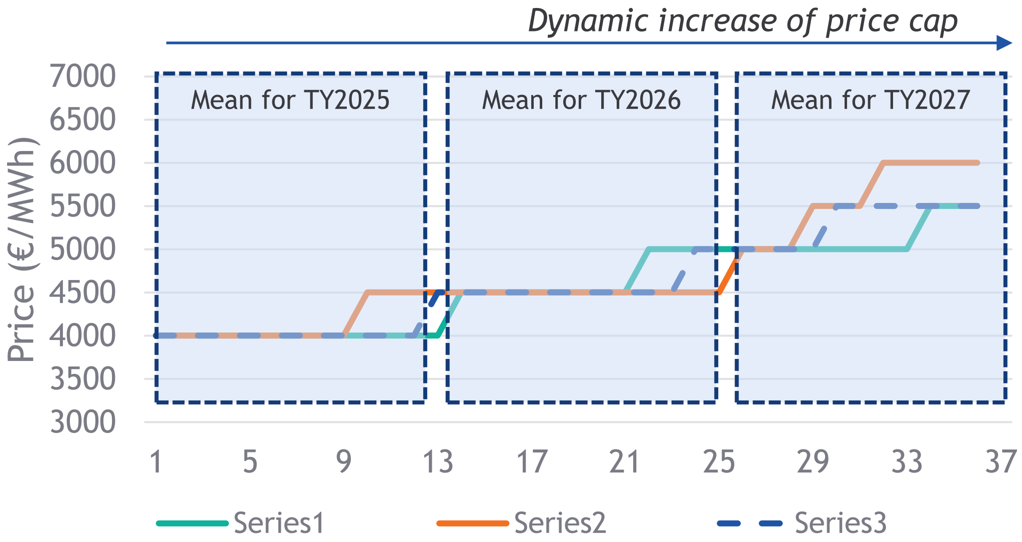
Estimate of maximum price cap values for each TY

1 Maximum Price Cap

Principles of the methodology

- Exogenous step before EVA simulation run
- Based on marginal prices from ERAA 2023 ED post-EVA Scenario A
- Price cap increase estimated over N consecutive climate years (CYs) per each FO sample from each TY as follows:
    - Starting value: 4 k€/MWh on 1st of January 2025
    - SDAC region, excluding UK00, UKNI and IE00
    - Price cap triggers based on price spikes and market cap rules*
    - Average of all simulated scenarios leading to one single price cap estimate per each target year

ERAA 2023 results	2025	2025	2025	2028	2028	2030	2030	2030	2033	2033	2033
ERAA 2024 TYs	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
15 FO scenarios ✖	1982	1983	1984	1982	1983	1982	1983	1984	1982	1983	1984
	1983	1984	1985	1984	1985	1983	1984	1985	1983	1984	1985
	…	…	…	…	…	…	…	…	…	…	…
	2014	2015	2016	2015	2016	2014	2015	2016	2014	2015	2016
		PC 2026		PC 2028		PC 2030					PC 2035



Note: Illustrative figure

Results

ERAA 2024

Year	Price cap (€/MWh)
2026	**4500**
2028	**5000**
2030	**6000**
2035	**6500**

ERAA 2023

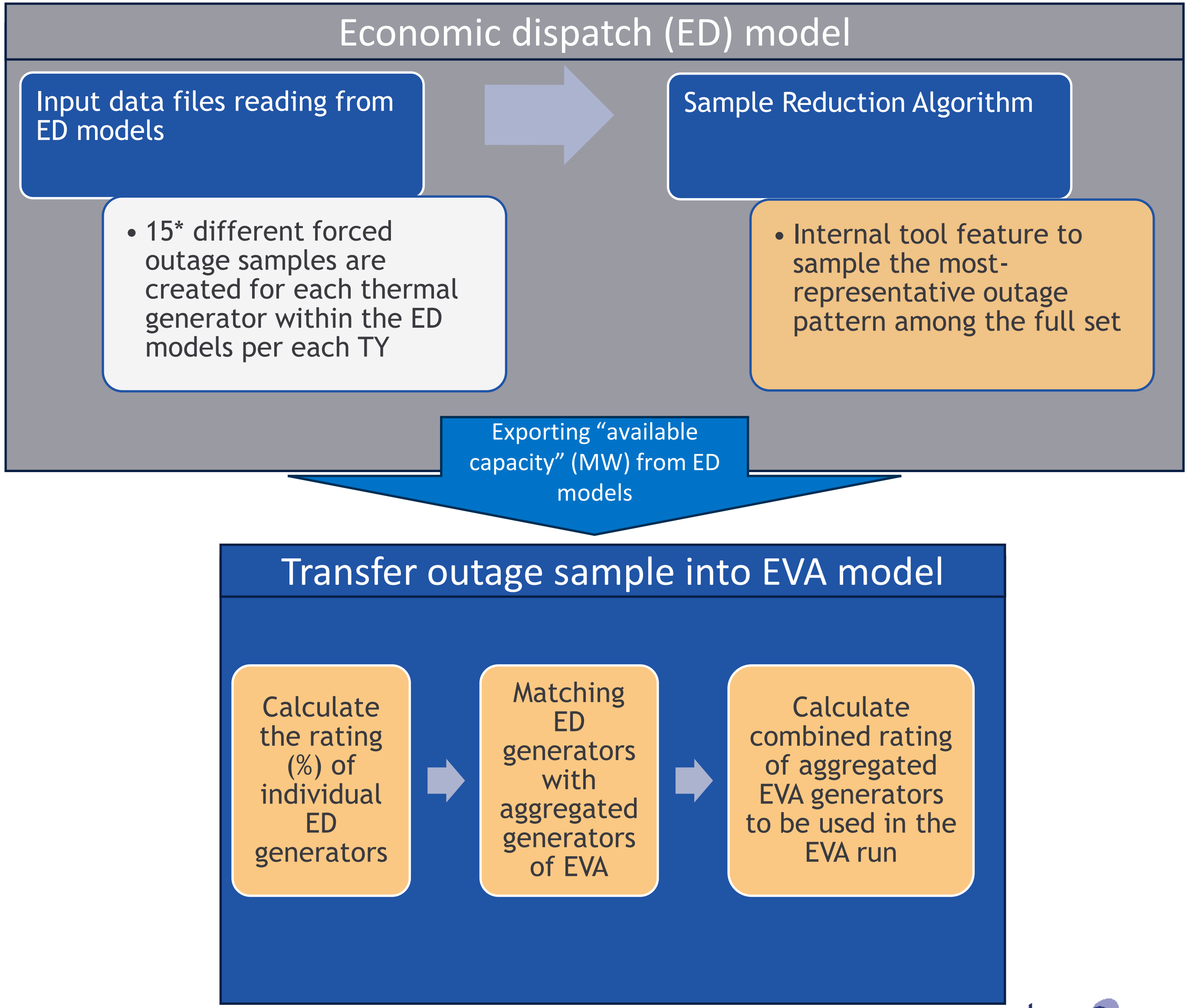
Year	Price cap (€/MWh)
2025	4500
2028	6000
2030	7000
2033	8500

*Harmonized Maximum and Minimum Clearing Prices Methodology for day-ahead markets (europa.eu)

Forced Outage modelling in EVA

Principles of the methodology

- Exogenous step prior to EVA run
- Improved consistency with ED model overcoming limitations of average derating approach
- Selecting one representative sample per each generator object directly from ED model
- Complexity is not negatively affected as one single representative sample is selected without increasing the number of stochastic variables



*Final number of FO samples will be decided upon convergence criteria of ED models.

Hurdle premium methodology

1. Reflect risk aversion of investors
2. Capture in the hurdle premium
3. Calibration of the hurdle premiums

Hurdle Premium methodology

Reflect risk aversion of investors in EVA modelling with a special focus on price risk:

- Choice of a market-based and transparent **increase in the WACC** *(ERAA Article 6.9.iii.a)*
- Limitations of a pure **WACC "base"** (Capital Asset Pricing Model) approach:
  - Capital Asset Price Model approach alone is not fully suitable for **non-normal revenue/price distributions**
  - **Non-symmetrical risks** cannot be properly reflected directly:
    - **Model risk:** perfect foresight, perfect market, transaction costs, etc.
    - **Policy risk:** uncertainty of policies, change of political framework, etc.

Proposal

Theorethical Framework on Risk Aversion Hypothesis

Utility Theory + Prospect Theory

Pragmatic methodology to estimate and calibrate hurdle premiums to add to WACC base*

WACC (CAPM-Based) + Hurdle Premium

Source: Boudt 2021

Hurdle Premium methodology

Risk aversion is captured within the hurdle premium

- The level of the **hurdle premium** is driven by two key parameters:
  1. **The revenue distribution and the downside risk** (under the simulation setup)
     - ➢ High price spikes & high volatility in revenue distribution = higher hurdle premium.
     - ➢ Intrinsically linked to the technology type and the merit order (e.g. Peak units VS Base Load generators).
  2. **Additional risks such as model risk and policy risk**
     - ➢ Difficult to capture real investors' expectations within the limited modelling framework.

Viability ensured if

$$\text{Expected Return} > \text{Hurdle Rate (R)}$$

$$\text{Hurdle Rate (R)} = \text{WACC base*} + \text{Hurdle Premium}$$

*In ERAA the WACC base is taken from official CONE studies and should be compliant with ACER giuidelines

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Hurdle Premium methodology

Calibration of the hurdle premiums based on specific technologies and modelling framework

1. **Definition of lower and upper bounds following heuristic approach:**
   - ➢ Lower bound: minimum nominal value of 5% for medium and long-term investments in electricity capacity.
   - ➢ Upper bound: study and stakeholder assessment lead to max hurdle rate of ca. 2 x WACC of full equity-founded project (ca 10% hurdle premium).

2. **Risk differentiation per technology based on a qualitative assessment:**
   - ➢ Low/Medium/High risk based on the two key risk drivers described before.
   - ➢ Hedging options are accounted and quantitative analyses are used to support the classification.

3. **Final calibration based on EOM revenues*:**
   - ➢ Differentiation between underlying market design with or without CM.
   - ➢ Calibration and values based on Belgium EOM can be extrapolated to other markets when model & policy risk are applicable and consistent, and revenue distribution & downside risk are similar.

Risk Driver	Model risk & Policy risk	Revenue distribution & Downside risk
Technology 1	Low/Medium/High	Low/Medium/High
Technology 2	Low/Medium/High	Low/Medium/High

Source: Boudt 2022

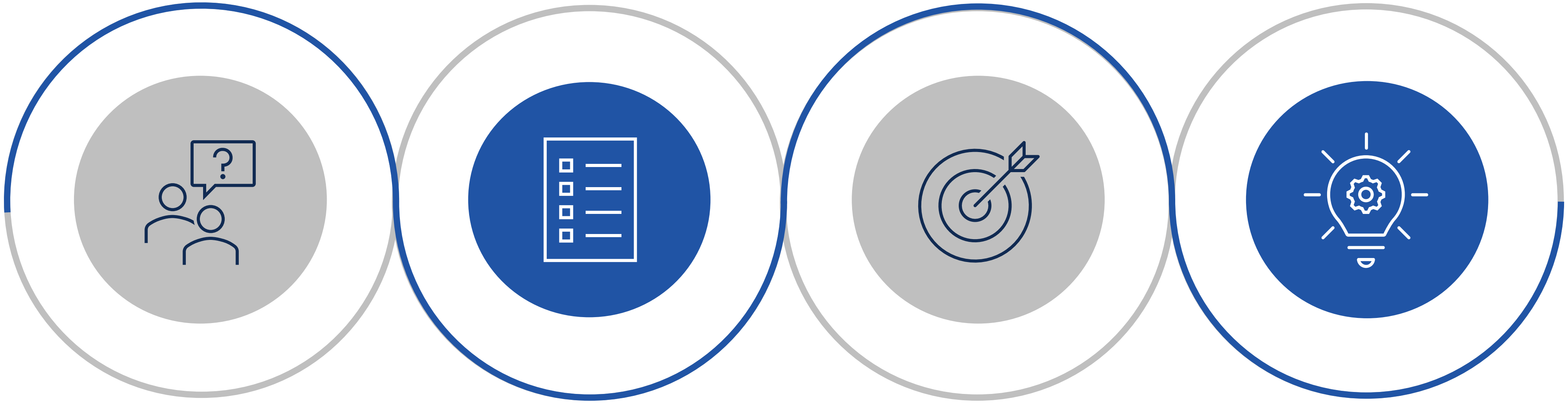
*The min and max real values of hurdle premium for ERAA 2024 EVA are 3% for existing gas CCGT and 6% for new OCGT capacity.

Revenue-based EVA

Gregorio Iotti
ERAA Market Study Team Convenor, APG

Background

What is the revenue-based EVA approach, and why are we testing it in ERAA?



CAUSE

High complexity in overall costs EVA model leads to the introduction of some simplifications (e.g. reduction of WS)

CONTEXT

Article 6.2 of the ERAA methodology allows for a “revenue-based” assessment of the economic viability capacity

GOAL

Investigate and benchmark the two EVA approaches and establish a robust framework for future ERAAs

APPROACH

Build on TSO experience with NRAA to establish a revenue-based EVA on the full pan-European perimeter

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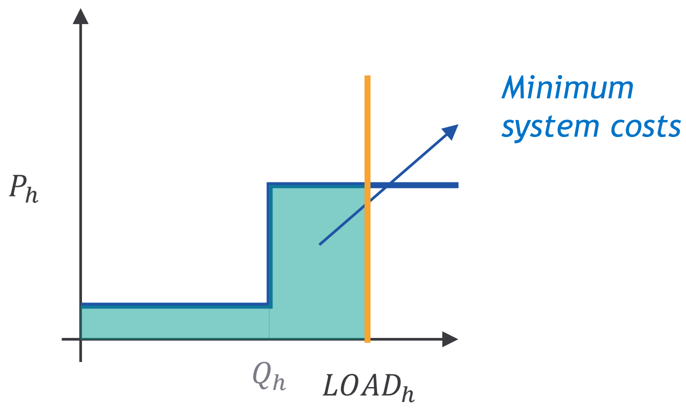
Both approaches can theoretically converge

Overall costs approach

Operational since ERAA 2021

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



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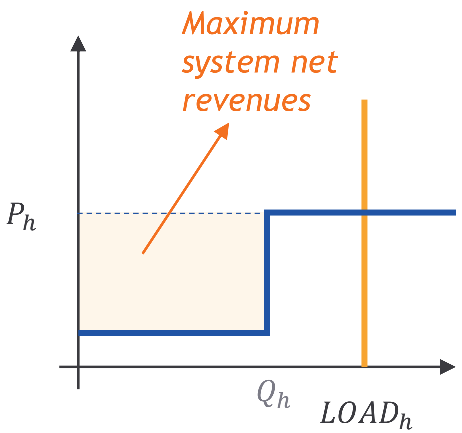
Under **a set of assumptions**:
- *Perfect competition*
- *Perfect foresight*
- *Shedding cost = price cap*

Revenue-based approach

Development stream of ERAA 2024

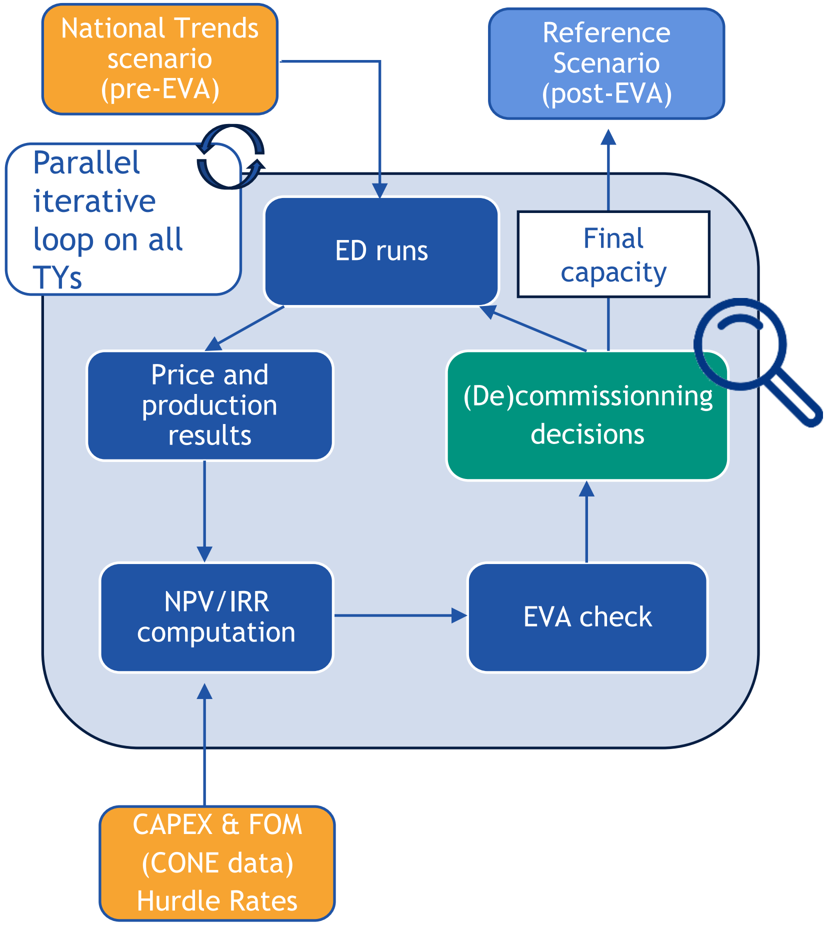
Investor revenues are:
- Inframarginal rents
- Additional revenue streams

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

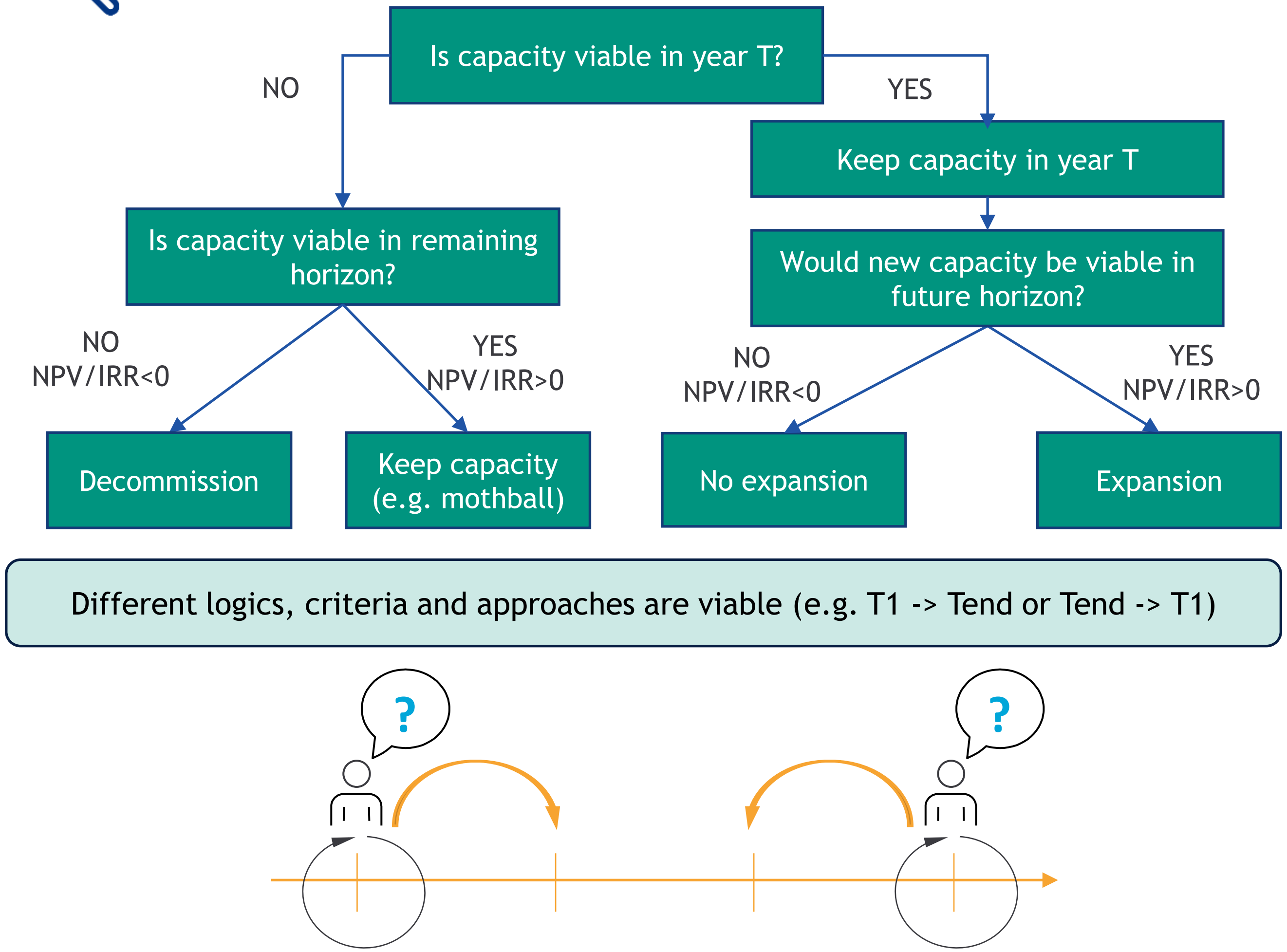


The revenue-based EVA leverage ED iterations to assess viability

Example of iterative loop



Example of investor decision logic in each iteration



Opportunities & Challenges of the revenue-based EVA

- Thanks to its iterative nature, each sub-problem is manageable in complexity, thus allowing to include a higher number of WS and FO samples
- The exogenous revenue & cost assessment can allow for higher control and possibilities on different revenue streams and value drivers
- Extending the approach to the whole European perimeter is challenging in terms of runtime and computational requirements*
- Simultaneous inclusion of all expansion candidates and EVA decisions (e.g. mothballing and life extension) is particularly challenging
- The results can be sensitive to a set of ruling criteria:
  - Choice of investors’ logic and assessed metrics
  - Criteria need to be defined to rule the entry/exit of capacity at each iteration (e.g. top/worst N viable units per bidding zone; +/- X MW per bidding zone)
  - “Convergence criteria” are needed to establish an end to the iterative approach (e.g. % all capacity within viability range)

*Tests are ongoing to establish the capabilities in term of max number of WS and FO samples

Conclusions & next steps

Lukas Galdikas,
ERAA Project Management, ENTSO-E

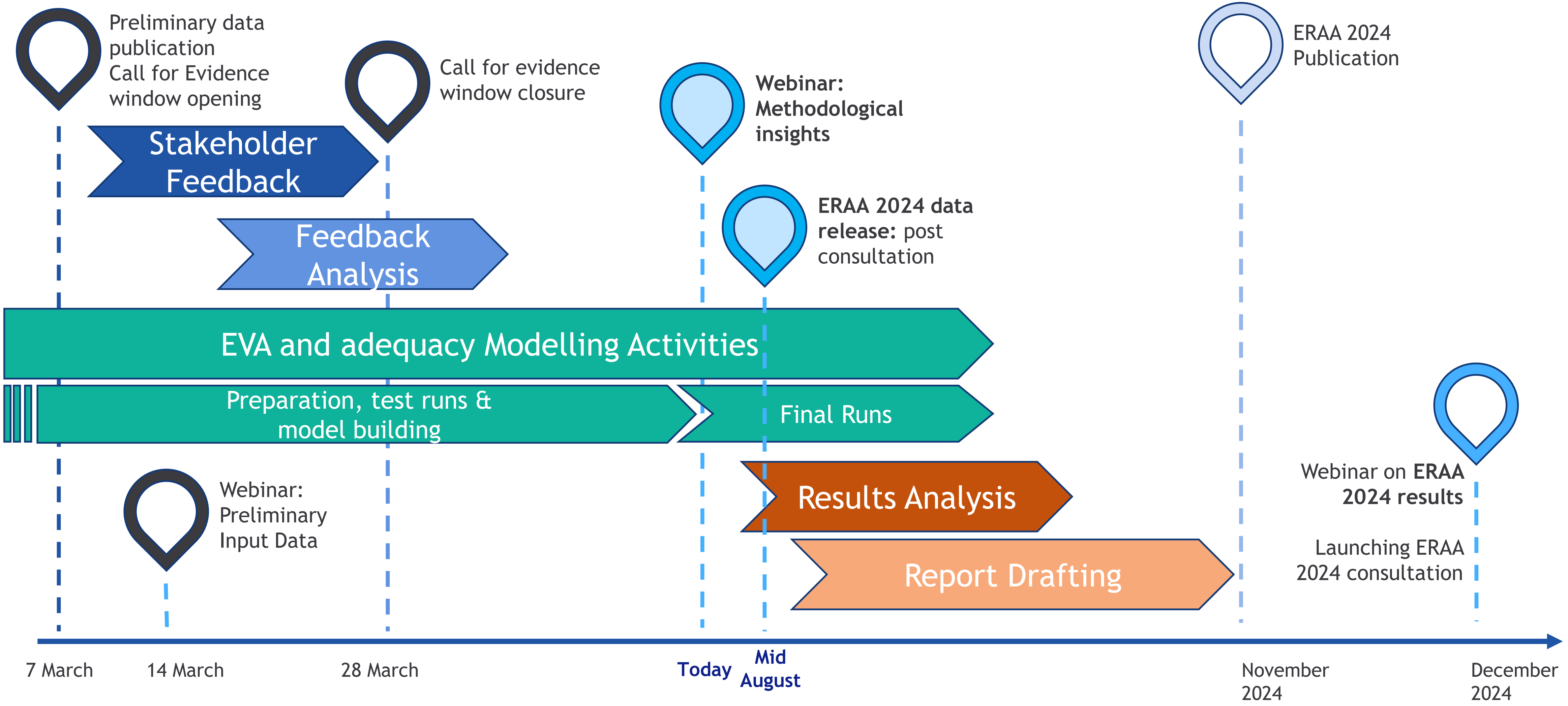
Take aways

The ERAA supports European transition towards net-zero system by assessing potential adequacy risks and informing decision makers and stakeholders.

Methodology continues to develop with support of valuable stakeholder feedback and close engagement with ACER.

- **Flow-based modelling significantly advanced** in two areas: (i) preparation of FB domains; and (ii) deployment of such domains within ERAA models. Nordic FB domains computed for the first time for a pan-European study
- **Weather Scenario selection was refined** after adoption of new Climate Database with three weather scenarios being identified as representative.
- Number of other **methodological enhancements** introduced in ERAA with focus **to enhance consistency** between EVA and Adequacy models.
- A **Revenue Based EVA** is being developed on European scale models building on TSOs experience and assess its potential adoption in future ERAAs.
- This year's ERAA also focused on **improved stakeholder engagement & transparency** regarding data publication.

Don’t forget to join us for the next public webinars & workshops



Thank you for your attention

Cooperation

Planning, cooperation and targeted measures are key for a secure electricity system.

Coordination

Adequacy issues deeply interlinked; regional coordination is crucial.

For any questions: info@entsoe.eu