Methodological developments for European Resource Adequacy Assessments

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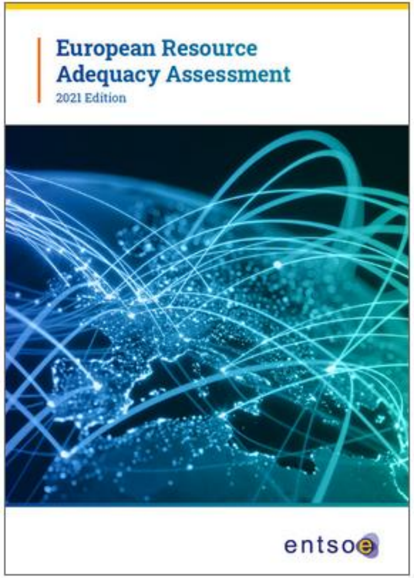
Agenda

- What is the ERAA?
- Methodological advancements of the first (2021) ERAA edition
- Improvements planned for future editions of the ERAA
  - Modelling methodology for implicit Demand Side Response (iDSR)
  - First implementation of iDSR in adequacy models



ERAA 2021 Edition[1]

[1] https://www.entsoe.eu/outlooks/eraa/

The ERAA Framework

PEMMDB

Net Generation Capacities

NTCs / Flow Based

Net Transfer Capacities
Flow Based Domains

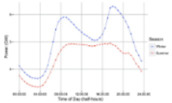
PECD

Capacity Factors

Hydro Database

Temperature profiles

DEMAND



Native demand forecasts

Modelling Tools

antares simulator

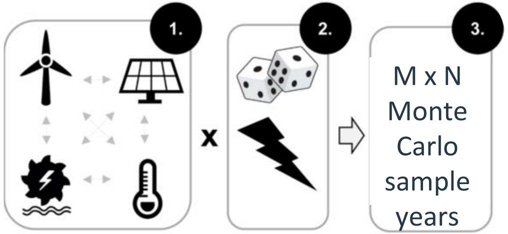
BID3 Electricity Market Model

GRARE developed by CESI Shaping a Better Energy Future

PowrSym

PLEXOS by Energy Exemplar

Monte Carlo Simulation



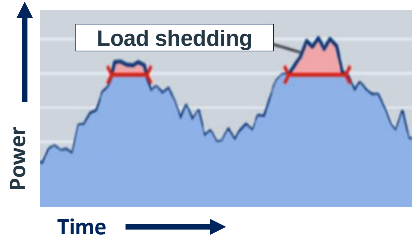
M years of independent climate data

N 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.

Future ERAA developments

Areas of improvement covered:

- Flow Based Market Coupling
- Economic Viability Assessment
- Demand Side Response

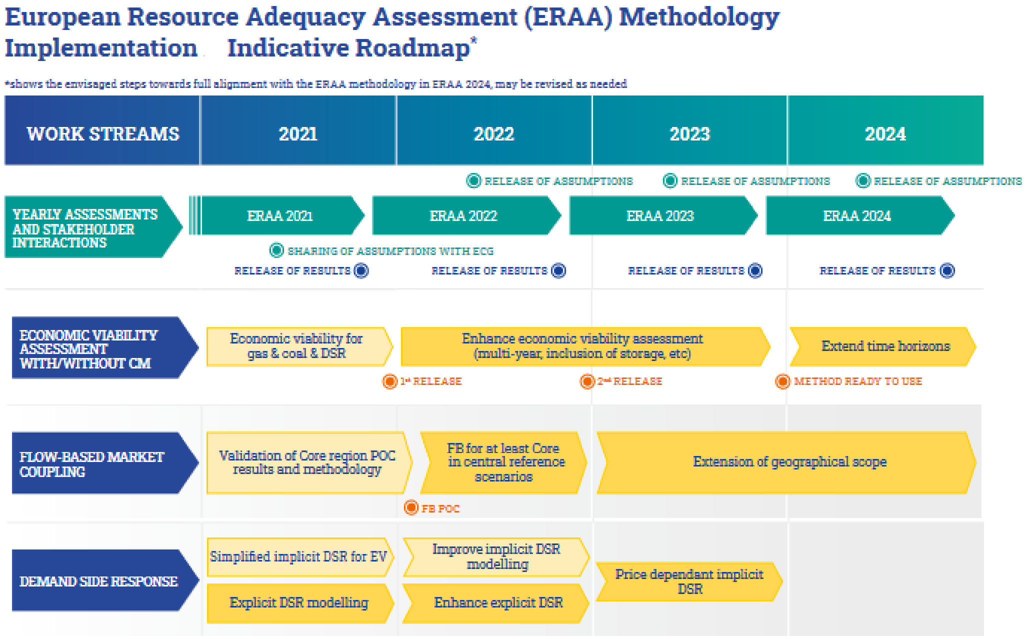


Fig. 1. Indicative Roadmap of the ERAA, taken from: ENTSO-E AISBL, “European Resource Adequacy Assessment - 2021 Edition”, Brussels, 2021.

Flow-Based Market Coupling

- Proof of Concept study in ERAA 2021
- Five step approach for retrieving FB domains:
  1. CNEC list definition
  2. Initial market simulation
  3. Load flow calculation
  4. Extraction of PTDF and RAM
  5. Clustering of domains

CNEC	A	B	C	RAM
CNEC 1	1	1	1	1
CNEC 2	1	1	-1	1
CNEC 3	1	-1	1	1
CNEC 4	-1	1	1	1
CNEC 5	1	-1	-1	1
CNEC 6	-1	-1	1	1
CNEC 7	-1	1	-1	1
CNEC 8	-1	-1	-1	1

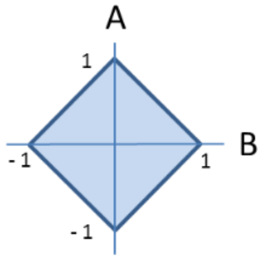


Fig. 2. Simple example of the FB domain structure, taken from: ENTSO-E AISBL, "European Resource Adequacy Assessment - 2021 Edition", Brussels, 2021.

Economic Viability Assessment (EVA)

- Assessment of the likelihood of **retirement**, **mothballing** and **new investments** of **generation assets** including different revenue streams
- The EVA shall assess the impact of existing and approved future **Capacity Mechanisms** (CM) in Member States
- ERAA 2021 included EVA in the form of a simplified **single-year** assessment for the target year 2025
- Two scenarios „with“ and „without“ capacity mechanism were considered

Economic Viability Assessment (EVA)

- Candidates for new investments: **Gas OCGT New ; Gas CCGT New ; DSR**
- Units with **existing CM, policy contracts** or **must-run CHP** (valid in 2025) cannot be retired
- **Nuclear, RES, hydro, batteries** and **DSR** cannot be retired
- **Risk aversion** as well as policy and multi-year risk considered through **hurdle premiums** per technology type[2]
- **Energy only market considered:** no additional revenues (e.g. heat, ancillary services, etc.)
- Results averaged for **7 climate years** (1983, 1984, 1990, 1995, 1996, 2006, 2009)
- **Value of Lost Load (VoLL)** set to **15 k€/MWh** in compliance with ACER‘s request
- **CO_2 price** set to **40 €/ton**

[2] K. Boudt, “Accounting for Model, Policy and Downside Risk in the Economic Viability Assessment of Investments in Electricity Capacity: The Hurdle Rate Approach”, 2021

Demand Side Response (DSR)

- Existing modelling of DSR: explicit interruptible load with fixed activation price(s)
- Future improvement: including price-reactive implicit DSR (iDSR)
  - Demand flexibility resources (e.g. electric vehicles, heat pumps)
  - Define availability (load) time series per DSR technology
  - Fixed flexibility time windows within which demand can be shifted subject to certain constraints

Implicit Demand Side Response (iDSR)

Methodology

- Two additional decision variables $\boldsymbol{p_i^{DSR}(k)}$ and $\boldsymbol{e_i^{DSR}(k)}$ s.t. a set of constraints, e.g.:
  - Consumptive limitations: $\underline{p_i}^{\mathrm{DSR}}(k) \leq p_i^{\mathrm{DSR}}(k) \leq \overline{p_i}^{\mathrm{DSR}}(k)$
  - Energy limitations: $\underline{e_i}^{\mathrm{DSR}}(k+1) \leq e_i^{\mathrm{DSR}}(k+1) \leq \overline{e_i}^{\mathrm{DSR}}(k+1)$
  - Boundary conditions: $e_i^{\mathrm{DSR}}(1) = e^0$

Implicit Demand Side Response (iDSR)

Model structure

- ERAA 21 NTC model, post-EVA without CM, pivotal year 2025
- Two historic climate years: 1985 and 2006
- Two geographic perimeters: “Tri-Lateral” and CORE CCR

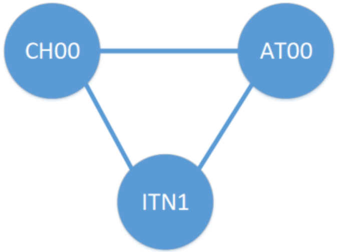


Fig. 3. “Tri-Lateral” model configuration including the Austrian, Swiss and Northern Italian bidding zones, own representation.

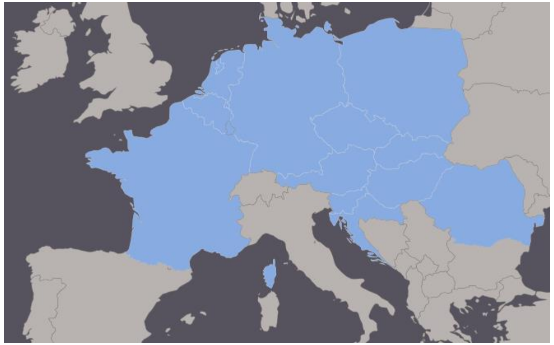


Fig. 4. Map highlighting the CORE CCR member states, own representation.

Implicit Demand Side Response (iDSR)

Input Data

- Load time series acquired through TRAPUNTA[3] and studies commissioned to the Austrian Institute of Technology (AIT)

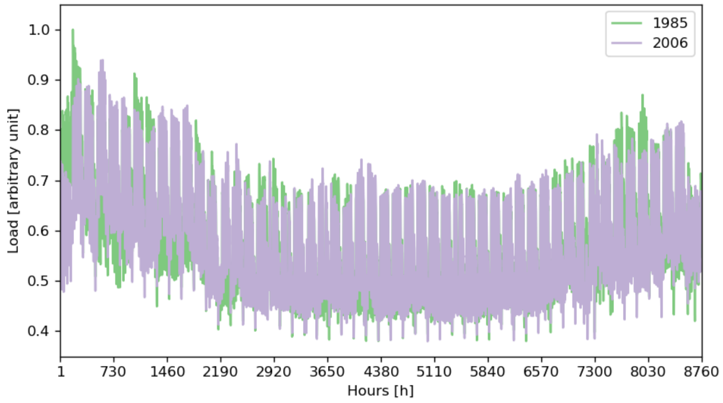


Fig. 5. Hourly load time series for the Austrian bidding zone used in the simulations, normalized to the maximum value of the dataset.

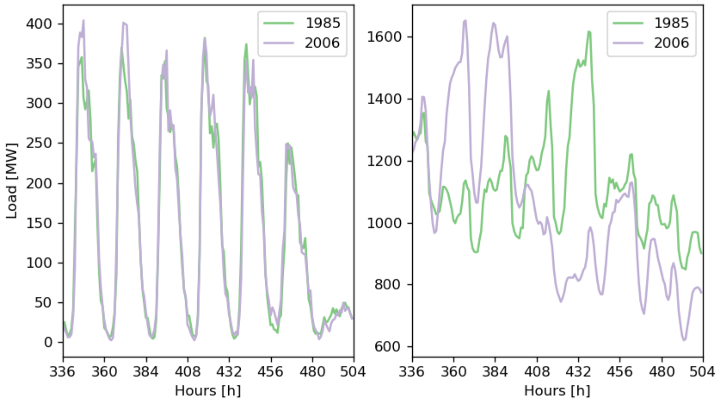


Fig. 6. Hourly load time series of electric vehicles (left) and heat pumps (right) for a selected period of 7 days of the respective climate years.

[3] see ENTSO-E AISBL, "ERAA 2021 - Demand Forecasting Methodology", 2021.

Implicit Demand Side Response (iDSR)

Results - benchmark

- Modelling horizon of one year using the tool Plexos[4]
- 20 random availability time series of thermal power plants
- Adequacy Indicators reported for the Austrian bidding zone

Geo. perimeter	CY	Unserved energy (GWh)	Unserved Energy Hours (h)
Tri-Lateral	1985	0.0014	0.05
Tri-Lateral	2006	685.49	385.10
CORE region	1985	1.30	3.80
CORE region	2006	0.01	0.20

Tab. 1. Adequacy indicators for the benchmark scenario ("base case").

[4] https://www.energyexemplar.com/plexos

Implicit Demand Side Response (iDSR)

Results - scenarios

- Two cases studied, 10% flexibility potential and 100% flexibility potential per technology (electric vehicles and heat pumps)
- Per scenario, different flexibility time frames (3h, 6h, 12h)
- CORE model proved to provide a more robust testing environment

Implicit Demand Side Response (iDSR)

Results

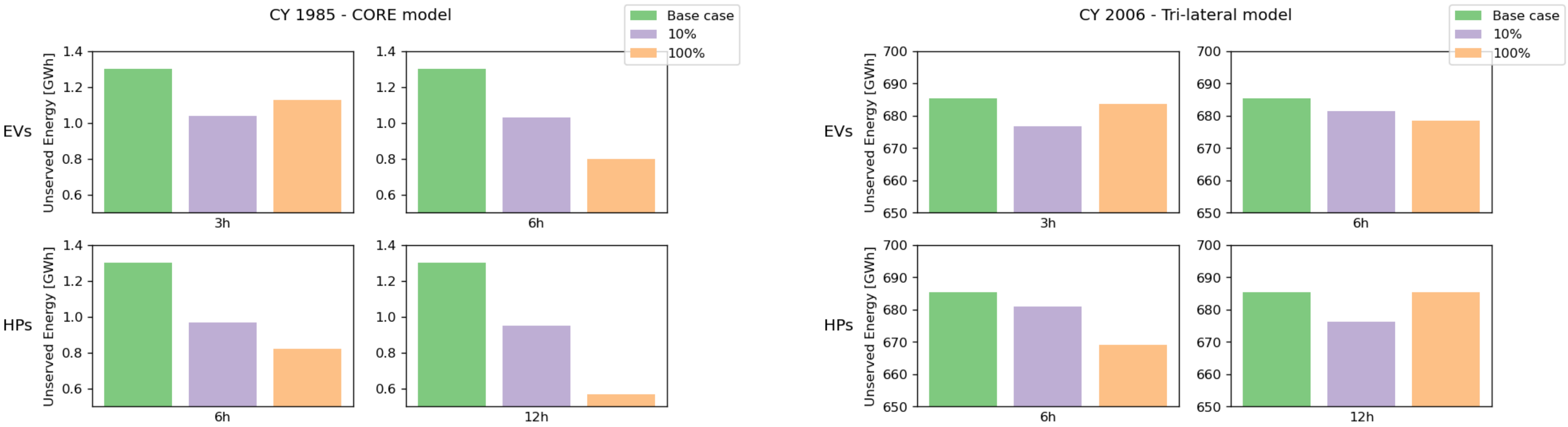


Fig. 7. Unserved energy in GWh for the climate year 1985 in the CORE configuration (left) and the climate year 2006 in the tri-lateral configuration (right).

Implicit Demand Side Response (iDSR)

Results – combined availability

- Simultaneous availability of EVs and HPs for iDSR purposes
- 10% assumed to be price-reactive
- 6h time window assumed for both technologies

Geo. perimeter	CY	Unserved energy (GWh)		Unserved Energy Hours (h)	
Tri-Lateral	1985	0.00	(-100%)	0.00	(-100%)
Tri-Lateral	2006	684.20	(-0,19%)	371.65	(-3,49%)
CORE region	1985	0.82	(-36,92%)	2.20	(-42,11%)
CORE region	2006	0.00	(-100%)	0.00	(-100%)

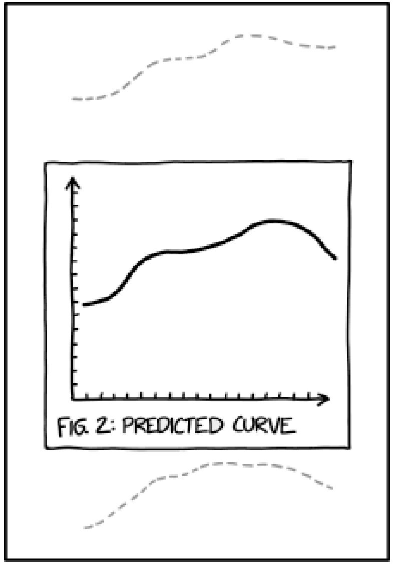
Tab. 2. Adequacy indicators for the combined (heat pumps + electric vehicles) scenario.

Conclusions and future work

- The methodology proved **successful** in achieving **endogenous demand flexibility**
- Approach requires **careful consideration** when choosing the flexible **demand share** and the hourly **time windows**
- Impact on national adequacy indicators overruled by global system perspective: consistent changes expected after the implementation of Local Matching constraint
- The future work includes the **fine-tuning** of the **assumptions** as well as the **deployment** of the methodology **in ERAA 2022**

Summary

- ERAA subject to significant methodological improvements in past, present and future
  - Transitioning from NTC to FB market coupling
  - Economic Viability Assessment
- Modelling of implicit DSR
  - Definition of a methodology
  - Successful testing in adequacy models
- Outlook



SCIENCE TIP: IF YOUR MODEL IS BAD ENOUGH, THE CONFIDENCE INTERVALS WILL FALL OUTSIDE THE PRINTABLE AREA.[5]

[5] https://xkcd.com/2311/

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EVA – Simplified problem description

Minimize

$$FixedCost_{new}u_{new} + \sum_h VarCost_{new}p_{new}^h +$$

$$+FixedCost_{exst}(1 - u_{exst}) + \sum_h VarCost_{exst}p_{exst}^h + VOLL \times \sum_h ENS_h$$

subject to:

$$p_{new}^h + p_{exst}^h + ENS_h = D^h \qquad \forall h$$

$$p_{new}^h \leq P_{new}u_{new}$$

$$p_{exst}^h \leq P_{exist}(1 - u_{exst})$$

Network cons.

$FixedCost$	Fixed cost adding FOM and CAPEX and reducing additional/CM revenues
$VarCost$	Variable cost adding fuel/non-fuel operation cost
$u_{exst/new}$	Decision variable on decommissioning/investment
$p_{exist/new}^h$	Production in MW for each hour
$P_{exist/new}$	Generating unit capacity
D^h	Demand for each hour

In the future additional revenues and CM revenues may be deducted from the FOM cost or added explicitely.

The decision variables are found in the LT simulation.

From a total Welfare perspective a unit is:

Viable	[FixedCost] < [GenCost reduction]
Non-viable	[FixedCost] > [GenCost reduction]

EVA – Simplified risk aversion consideration

A risk averse investor:

- will not invest if that decision is based on revenues from a few hours in few scenarios that might not realize in reality
- will not invest if the decision includes the possibility of low profit in several scenarios

The simplified risk consideration in ERAA 2021 was achieved through the addition of hurdle premiums to the WACC[1]:

➔ Risk averse units increase their WACC* assumption which is used to calculate the annuity.

$$Annuity = CAPEX \times \frac{(WACC + Hurdle\ premium)}{1 - \left(\frac{1}{1 + (WACC + Hurdle\ premium)}\right)^{Lifetime}}$$

*The weighted average cost of capital (WACC) is the rate that a company is expected to pay on average to all its security holders to finance its assets.

The final Hurdle Rate used per each technology type is equal to the WACC-base plus the technology hurdle premium.

[1] K. Boudt, "Accounting for Model, Policy and Downside Risk in the Economic Viability Assessment of Investments in Electricity Capacity: The Hurdle Rate Approach", 2021

10% Results

- EV

Flex.	Geo. perimeter	CY	Unserved energy (GWh)	Unserved Energy Hours (h)
3h	Tri-Lateral	1985	0.00026	0.05
	Tri-Lateral	2006	676.81	371.85
	CORE region	1985	1.04	3.40
	CORE region	2006	0.01	0.20
6h	Tri-Lateral	1985	0.00026	0.05
	Tri-Lateral	2006	681.47	369.4
	CORE region	1985	1.03	3.20
	CORE region	2006	0.01	0.20

- HP

Flex.	Geo. perimeter	CY	Unserved energy (GWh)	Unserved Energy Hours (h)
6h	Tri-Lateral	1985	0.00	0.00
	Tri-Lateral	2006	680.93	377.80
	CORE region	1985	0.97	2.60
	CORE region	2006	0.00	0.00
12h	Tri-Lateral	1985	0.00	0.00
	Tri-Lateral	2006	676.27	368.25
	CORE region	1985	0.95	3.00
	CORE region	2006	0.00	0.00

100% Results

- EV

Flex.	Geo. perimeter	CY	Unserved energy (GWh)	Unserved Energy Hours (h)
3h	Tri-Lateral	1985	0.00	0.00
	Tri-Lateral	2006	683.57	361.25
	CORE region	1985	1.13	3.60
	CORE region	2006	0.00	0.00
6h	Tri-Lateral	1985	0.00	0.00
	Tri-Lateral	2006	678.60	350.90
	CORE region	1985	0.80	2.20
	CORE region	2006	0.00	0.00

- HP

Flex.	Geo. perimeter	CY	Unserved energy (GWh)	Unserved Energy Hours (h)
6h	Tri-Lateral	1985	0.00	0.00
	Tri-Lateral	2006	669.12	355.90
	CORE region	1985	0.82	2.20
	CORE region	2006	0.00	0.00
12h	Tri-Lateral	1985	0.00	0.00
	Tri-Lateral	2006	685.33	364.00
	CORE region	1985	0.57	1.80
	CORE region	2006	0.00	0.00

Fuel prices (2025)

Fuel Type	Price [€/net GJ]
Hard Coal	2.3
Lignite (BG-MK-CZ)	1.4
Lignite (SK-DE-RS-PL-ME-UKNI-BA-IE)	1.8
Lignite (SL-RO-HU)	2.37
Lignite (GR-TR)	3.1
Natural Gas	5.57
Heavy Oil	10.56
Light Oil	12.87
Oil shale	1.56

CO_2 price: 40€/ton