etch
Energy Transmission Competence Hub

Considering resilience in decision-making for power system planning

Matteo Rossini, Hakan Ergun

Department of Electrical Engineering (ESAT), **KU Leuven**, Belgium
Etch competence hub of **EnergyVille**, Belgium

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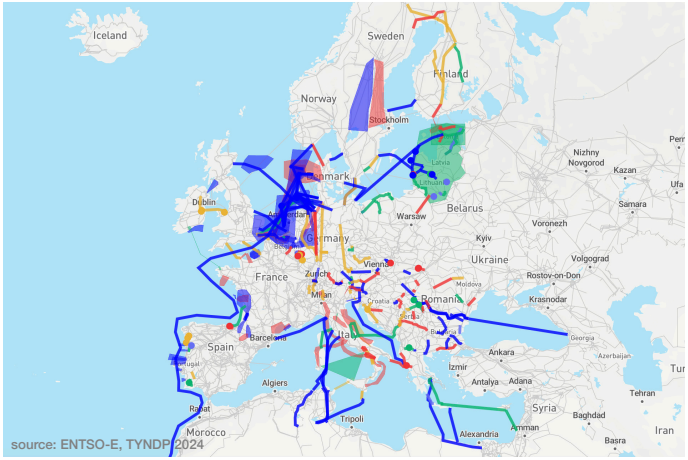
Energy Ville
KU LEUVEN

Multiple decisions are made at different stages



System needs

Investment opportunities

Conceptualization

"Which variant?"

CONCEPT SELECTION

Development

FEASIBILITY	PERMITTING
"Is it technically and economically viable?"	*"Can it be consented?"*

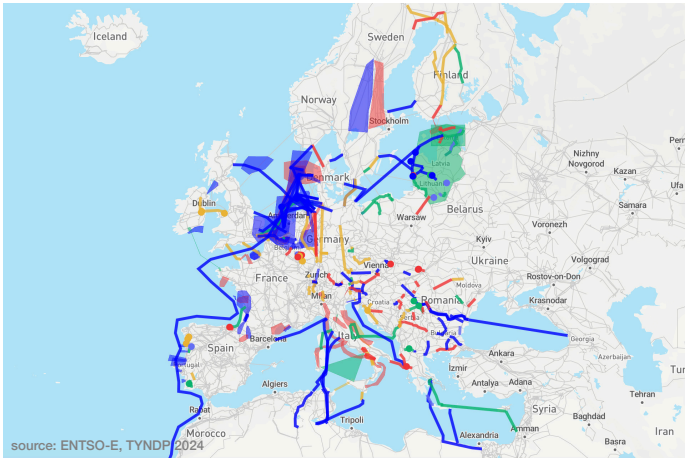
FINAL INVESTMENT DECISION

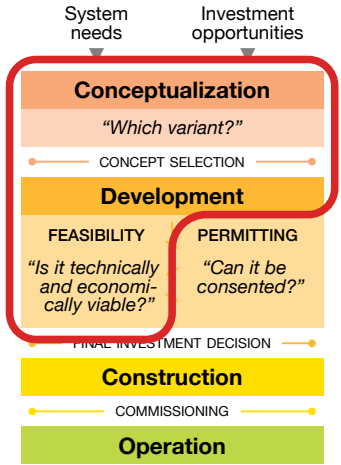
Construction

COMMISSIONING

Operation

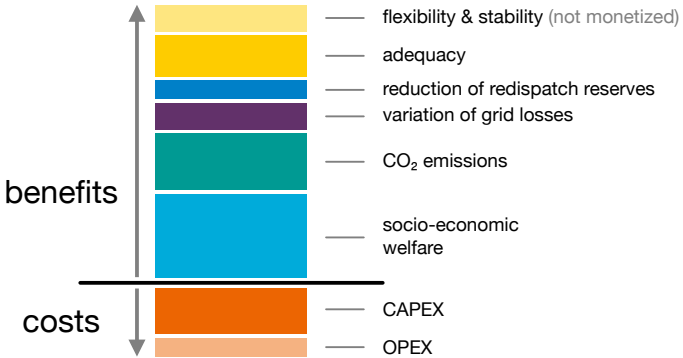
Multiple decisions are made at different stages





Projects are assessed using a CBA approach

ENTSO-E CBA guideline



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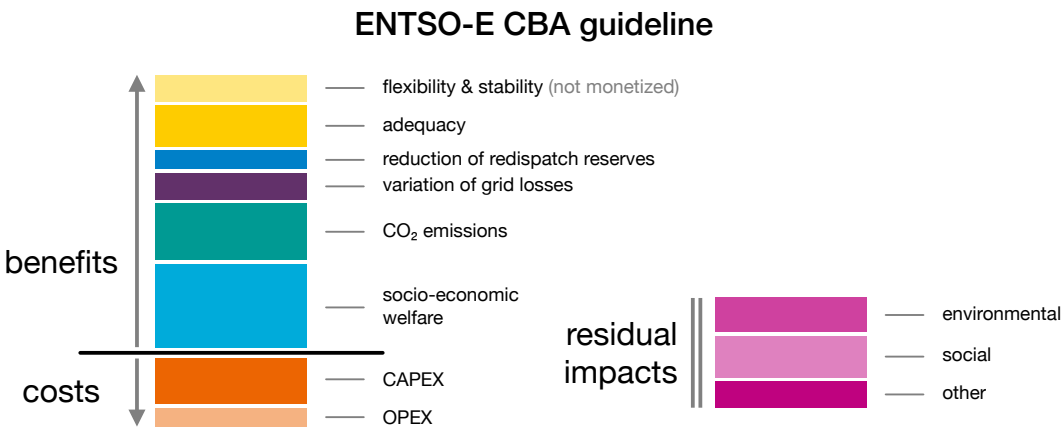
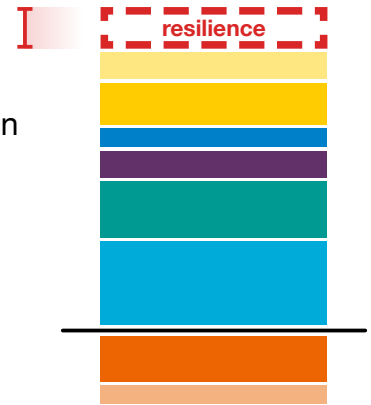


Resilience is not included in CBA

How to consider resilience in power system planning?

Q1

How to quantify
a project's contribution
to resilience?



How to consider resilience in power system planning?

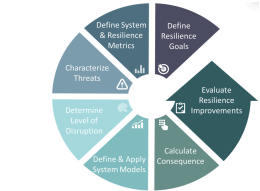
Q1

How to quantify a project's contribution to resilience?

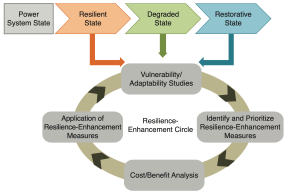
Q2

How to integrate resilience alongside other objectives?

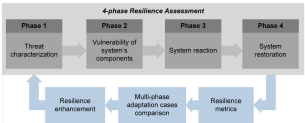
Several resilience frameworks proposed in the past decade



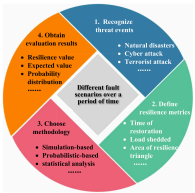
Sandia National Laboratories (2014)



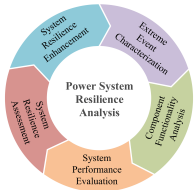
M. Panteli and P. Mancarella (2015)



S. Espinoza, M. Panteli, et al. (2016)



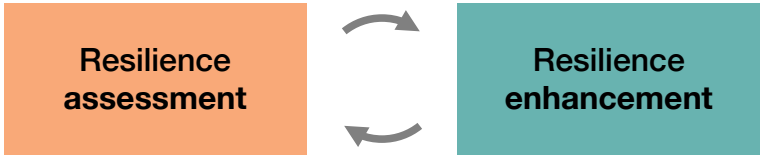
Z. Bie, Y. Lin, G. Li, F. Li (2017)



Z. Li, M. Shahidehpour, et al. (2017)

NREL (2019)

Resilience frameworks lead to two processes



As noted by:

M. Panteli and P. Mancarella, **"The grid: Stronger, bigger, smarter? Presenting a conceptual framework of power system resilience,"** IEEE Power and Energy Magazine, 2015

F. H. Jufri, V. Widiputra, and J. Jung, **"State-of-the-art review on power grid resilience to extreme weather events: Definitions, frameworks, quantitative assessment methodologies, and enhancement strategies,"** Applied Energy, 2019

Proposed framework for power system resilience analysis

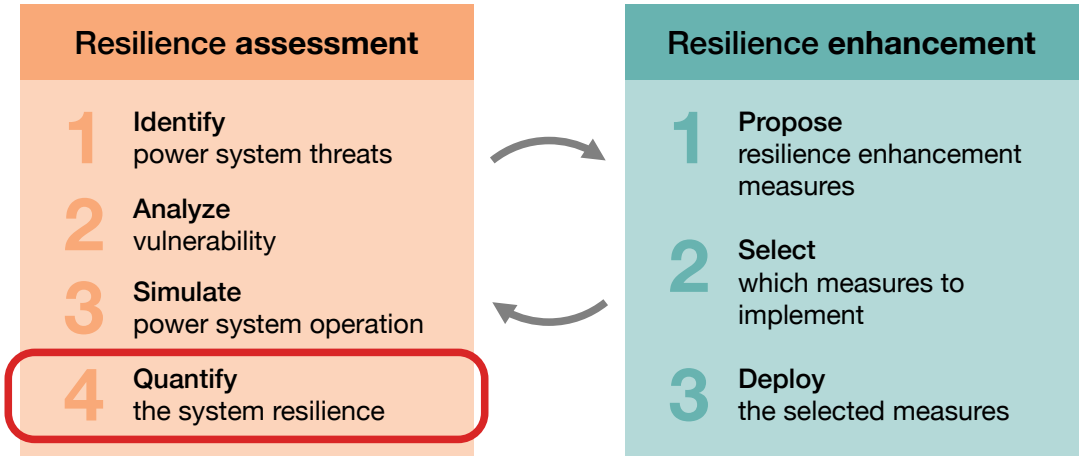
Resilience assessment

1. **Identify** power system threats
2. **Analyze** vulnerability
3. **Simulate** power system operation
4. **Quantify** the system resilience

Resilience enhancement

1. **Propose** resilience enhancement measures
2. **Select** which measures to implement
3. **Deploy** the selected measures

Q1: How to quantify an investment's contribution to resilience?



Q1: How to quantify an investment's contribution to resilience?

By comparing two assessments: with and without the investment

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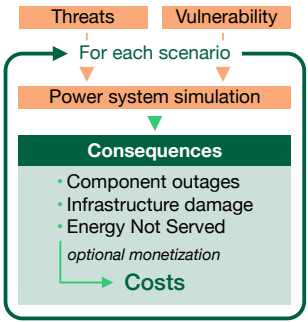
1 **Evaluate consequences** for each scenario



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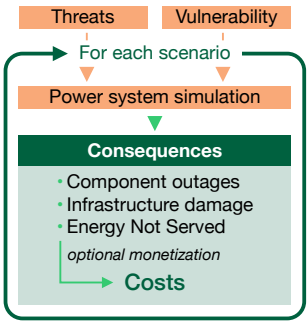
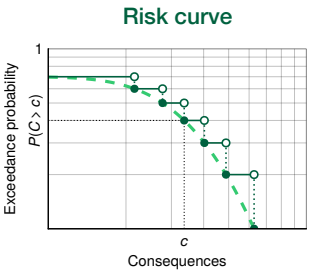


2 Aggregate consequences from different scenarios



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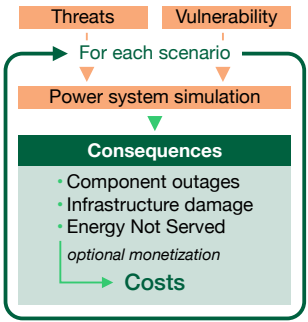

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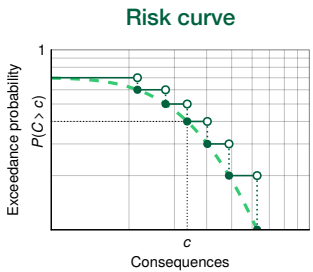
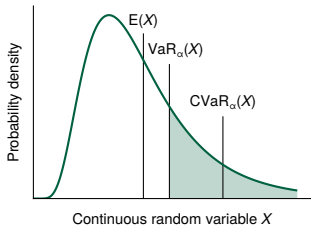
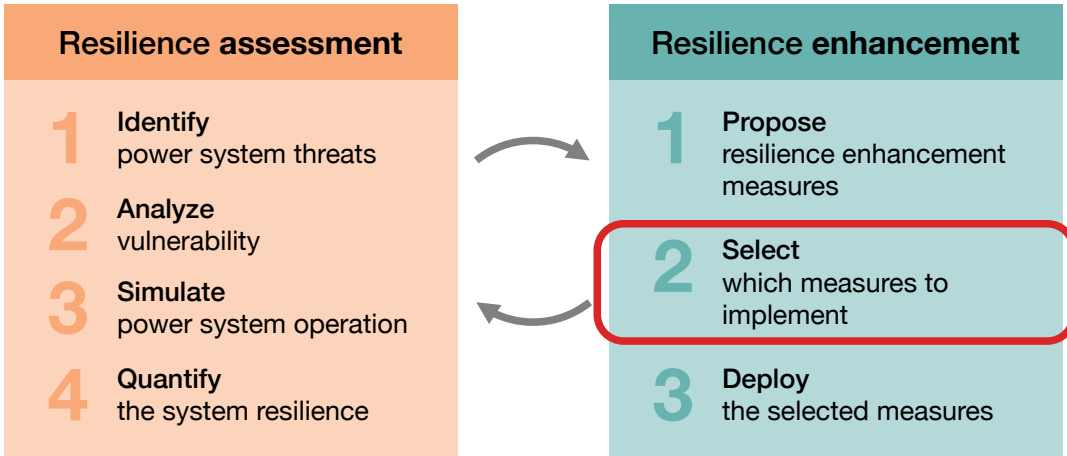


3 Compute the Conditional Value at Risk



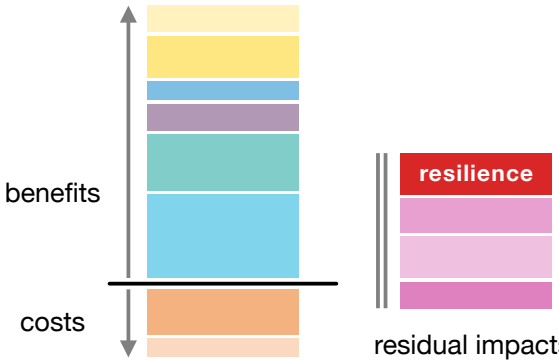
- ✔ captures the tail behavior
- ✔ not affected by low-impact, high probability events

Q2: How to integrate resilience alongside other objectives?



Q2: How to integrate resilience alongside other objectives?

Approach A: As a residual impact in CBA



✔ better than nothing

✔ does not require monetization

✘ resilience improvement not directly comparable to CBA benefits

The easiest approach

Q2: How to integrate resilience alongside other objectives?

Approach B: As a monetized benefit in CBA

- ✔ resilience directly comparable to other benefits
- ✘ requires monetization
- ✘ while most other benefits are certain (under the CBA assumptions), the resilience benefit is an expected value

Best suited for project assessment

Q2: How to integrate resilience alongside other objectives?

Approach C: As a criterion in Multi-Criteria Decision Analysis (MCDA)

Broad family of decision methods:

- **Full aggregation** methods

$$score = \sum_{c \in Criteria} weight_c \cdot score_c$$

- **Outranking** methods
- **Reference level** methods

✔ does not require monetization

✔ no need to aggregate consequences beforehand

✘ results depend on the decision-maker's preferences, which may be hard to assess

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Best suited for ranking alternatives in the conceptualization stage

Conclusions

1 An investment's contribution to resilience can be quantified by the variation in risk
Proposed metric: CVaR of the consequences of the simulated extreme events

2 Multiple approaches are possible to integrate resilience alongside other objectives
MCDA is best for ranking alternatives, while CBA is best for assessment

"All models are wrong, but some are useful."

Thoughts to share?

Email me at **matteo.rossini@kuleuven.be**