EMP-E 2021: Re-Energising Sustainable Transitions in Europe

Energy Modelling Platform for Europe

Energy System Modelling, Methods & Results to support the European Green Deal

26th to 28th October · online

# Strategic development of the Pan-European power network considering long-term uncertainties

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26th October 2021

Parallel Session 3: Capacity Planning amid Uncertainty

hosted in cooperation with the European Commission

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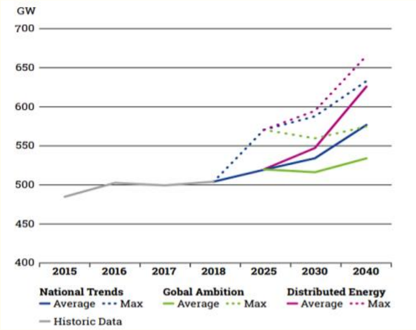
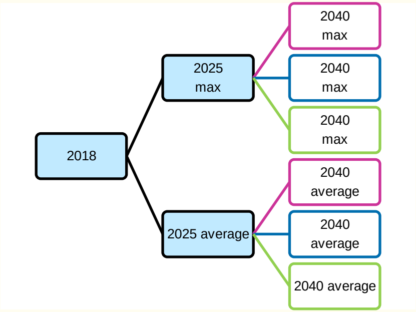
# Planning under long-term uncertainty

- The system evolution is affected by
  - Short-term uncertainties (operational timescale)
  - Long-term uncertainties (investment timescale)
- Uncertainty is multi-dimensional
  - Various sources
  - Spatial, temporal, magnitude, technological characteristics
- Scenario tree representation
  - Critical nodes that affect multiple scenarios
- Risk (regret)
  - Overinvestment / underutilisation of assets
  - Underinvestment / load curtailment

TYNDP2020: Peak electricity demand[1]




[1] https://eepublicdownloads.azureedge.net/tyndp-documents/TYNDP_2020_Joint_Scenario_Report_ENTSOG_ENTSOE_200629_Final.pdf

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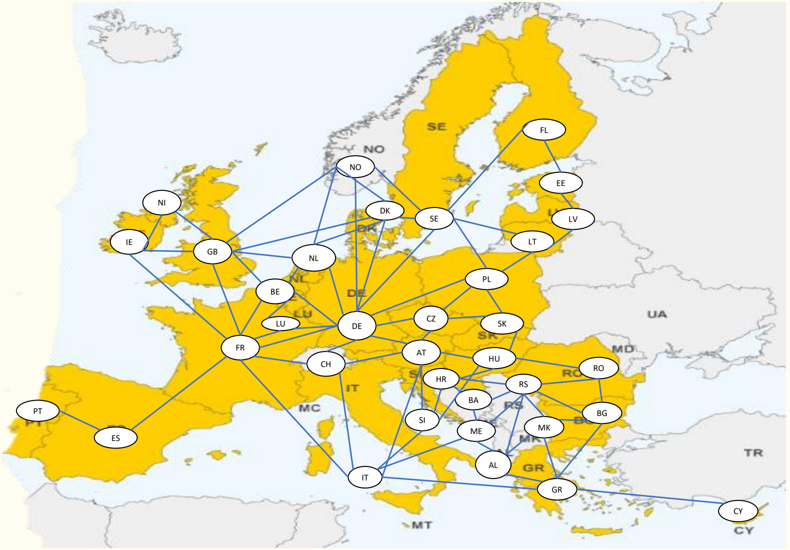
# Why consider uncertainty in transmission planning?

- Deterministic planning carries large risk of inefficient investment (regret)
- Planning frameworks that consider uncertainty are fundamental for identifying openings for strategic actions
- Conventional investment options in power systems are irreversible, capital intensive and have long commissioning times
- Non-network (smart) investments are smaller scale, have faster project completion, and offer flexibility (investment and system)
  - Managerial flexibility: ‘fit-and-forget’ vs. ‘wait-and-see’
  - Hedging tools against uncertainty → Reduce risk

# Why consider the network?

- Large connections of renewable capacity in the Pan-European power system
- Expected electrical load growth
- Transmission investments required
  - Accommodate load increase
  - Facilitate power flow (RES)




- Objectives:
  - Identify optimal conventional and energy storage investments for a 40-year horizon
  - Quantify the Option Value (OV) of energy storage as smart investment solution

# Problem formulation and uncertainty representation

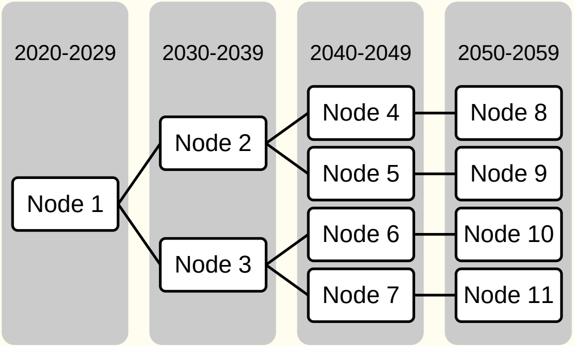
**min**{ E[Investment Cost + Operational Cost] }

subject to:

i) Investment constraints (MILP)
ii) Operational constraints (LP)
- Power Flow equations
- Transmission constraints
- Generation constraints
- Storage constraints

- Multi-stage stochastic optimization problem → strategic actions
- Solved using a Nested Benders decomposition approach

- Multiple sources of uncertainty
  - Wind deployment
  - Solar PV deployment
  - Investment cost of storage
  - Peak demand
- Magnitude, Location, Timing



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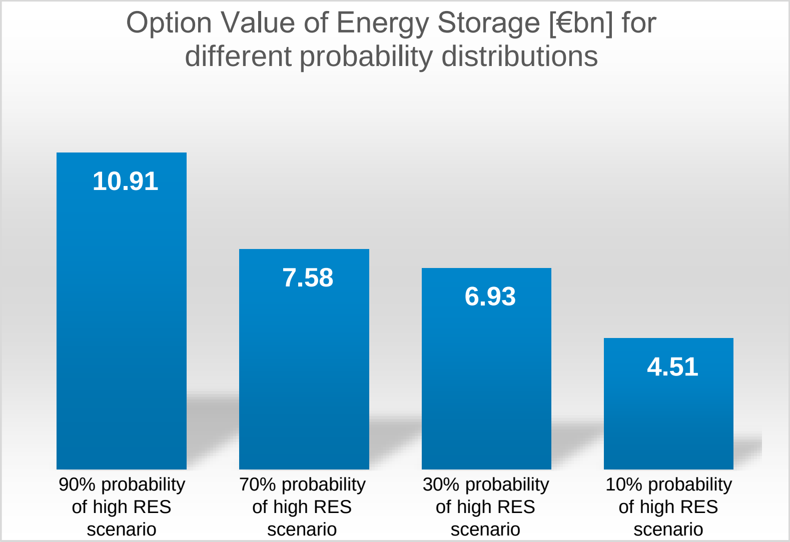
# Key observations (1)

1. Energy storage has a high OV
2. OV grows with the likelihood of connection of large RES capacity
   - greater potential to contribute to system economics as storage facilitates higher RES integration



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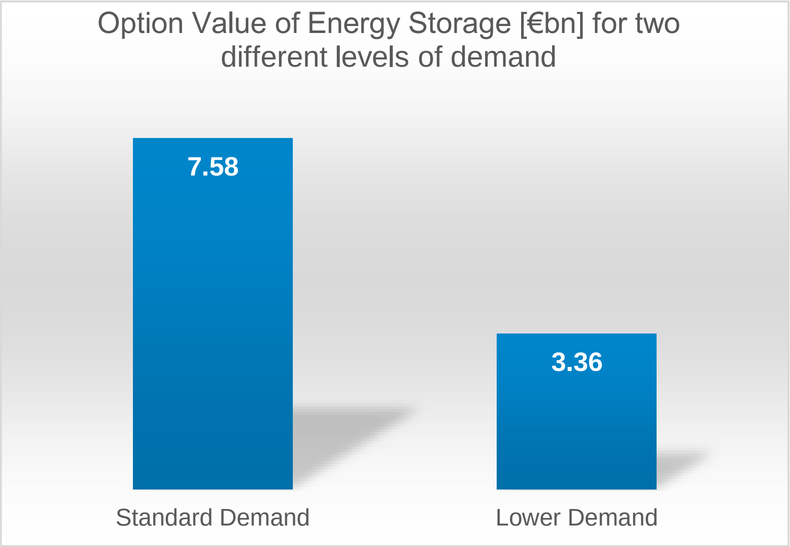
# Key observations (2)

3. OV grows with the level of demand
   – greater potential to contribute to system economics
   – greater potential for conventional reinforcement deferral and displacement



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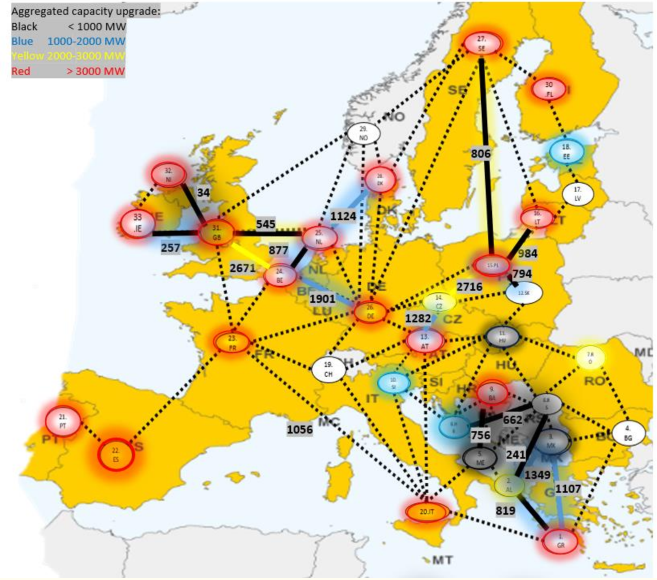
# Energy storage in 2050

- Wide-scale deployment across Europe
- Approximately €4bn (15%) reduced conventional reinforcement cost
- Operating primarily to mitigate congestion and accommodate RES generation



# Conclusions

- An adequate planning framework that considers multi-dimensional uncertainty is crucial to avoid large regret
- Smart options like energy storage can act as hedging tools against uncertainty
  → minimise risk
- Planning with energy storage:
  - Offers investment flexibility
  - Facilitates RES generation
- The OV of energy storage in the Pan-European system is significant and grows with higher levels of RES capacity and demand

➢ Regulation should recognise the OV of energy storage, incentivise strategic investment decision-making, and facilitate market integration

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# Thank you

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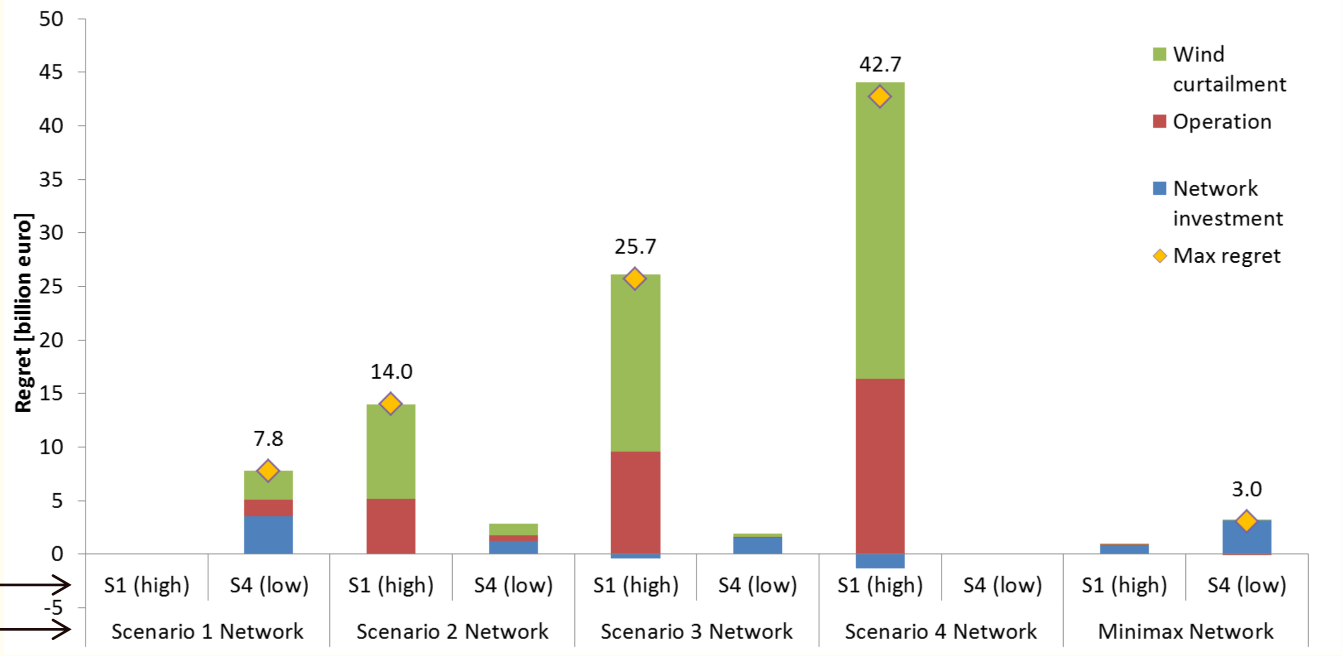
# Appendix A: Regret in deterministic planning




Realisation

Network built

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# Appendix B1: Modelling challenges

- Severe challenges related to problem size
- Consideration of large scenario trees - numerous multivariate nodes
  - Multiple sources of uncertainty expand tree size exponentially
  - Build times increase importance of time resolution
- Novel technologies introduce coupling in the problem structure
  - Storage Operation → time coupling
- Numerous technologies in addition to traditional assets
  - Binary variables
- Renewables and demand patterns
  - Expansion of the operational state-space

**Need for Decomposition & Reformulation**

**Need for Convexification**

**Optimal choice of representative time points**

*Traditional optimisation methods are reaching their **computational limits***

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# Appendix B2: Overcoming modelling challenges

- Undecomposed problem → Intractability
  - Lack of convergence due to immense state space
- Classic Benders Decomposition → Intractability
  - Not enough cut constraints
- Multi-Cut Benders Decomposition with Parallel Implementation →Intractability
  - Large number of cut constraints, still not leading to convergence
- Nested Benders Decomposition with the use of Discretization (Typical Days)

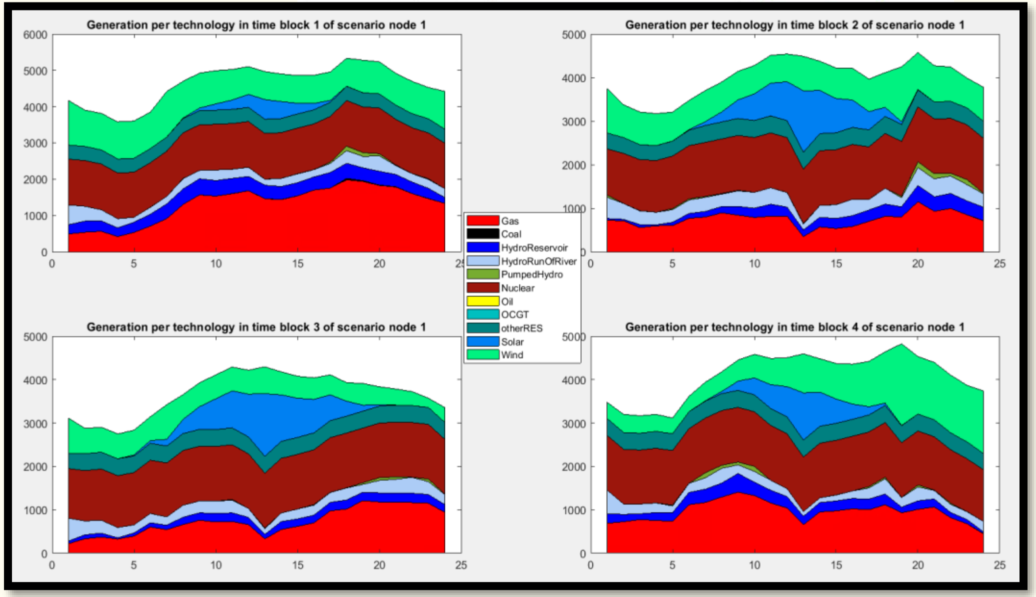
Classic Benders approach involving the generation of a single cut constraint per iteration.

Numerous cut constraints appended per iteration at the master, aiming towards speed of convergence.

Forward and backward passes of the formulation increase the accuracy in the selection of Lagrange multipliers.

# Appendix C1: Generation mix 2020

The 2020 generation mix involves significant amount of electricity generation from thermal units, mainly including Gas, Nuclear, OCGT. RES generation is relatively limited.



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# Appendix C2: Generation mix 2050

The 2050 generation mix involves significant amount of electricity generation from wind and solar, while the generation from thermal units is limited.