Case Study 2:
Transmission planning under uncertainty

EDF, April 11, 2018

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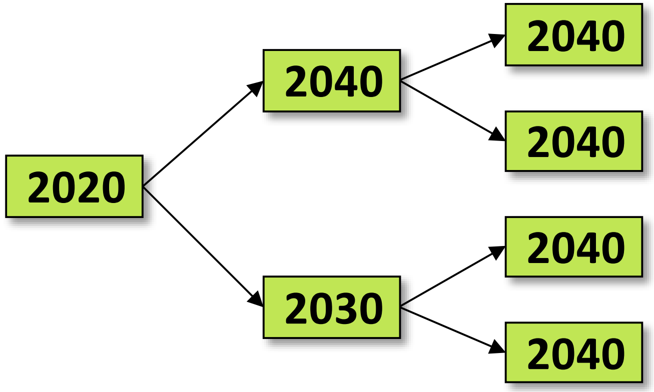
Case Study definition

"EU-wide transmission planning under uncertainty"

- Focus on the high-voltage electricity sector
- EU-wide scope
- Multi-stage (from 2020 to 2040)
- Explicit consideration of long-term uncertainties



Case Study objectives

The objectives of this case study are:

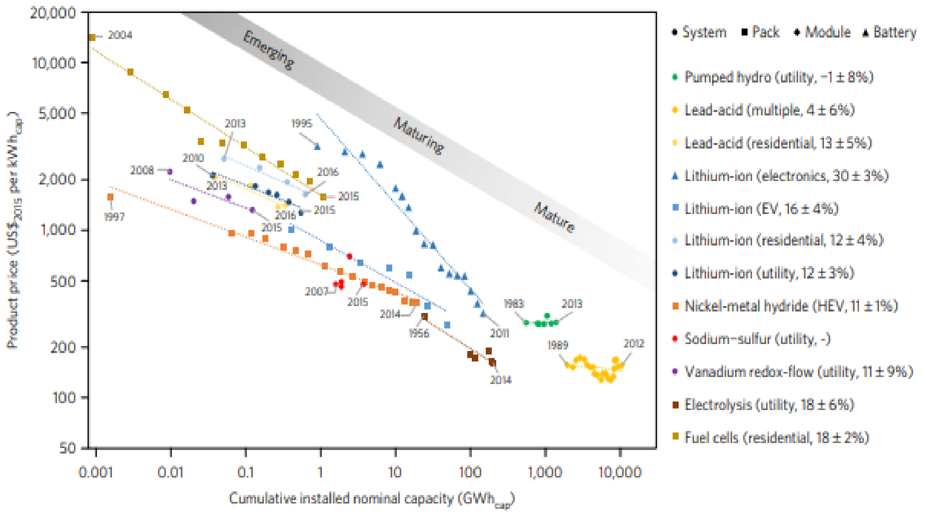
1. Demonstrate tool's ability to carry out **system planning under uncertainty**
   → important technical novelty set to increase in relevance
2. Identify **optimal development pathways** for the European transmission system under future uncertainty
   → minimum regret capital commitments – inform European TSOs
3. Assess the **impact of long-term uncertainty** on planning
   → inform regulatory framework
4. Assess the **value of flexible non-network technologies** (storage and demand-side)
   → inform future innovation directions

Sources of uncertainty

Historically, system planning has been carried out against a **single scenario**.

However, **planning now entails significant uncertainty**:

- Location/size/type of **new generation**
- Electrification of **transport & heat**
- Investment cost of **new technologies**



Evolution of energy storage CAPEX– O. Schmidt et al., Nature Energy, 2017.

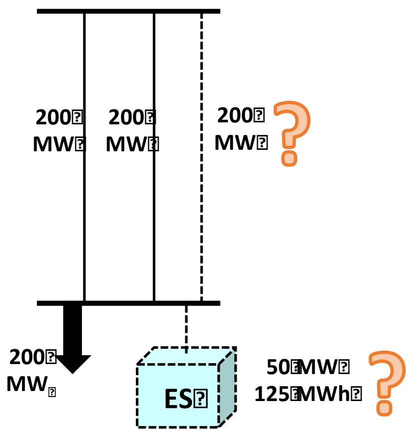
Why is uncertainty important?

- Capital decisions in power systems are **largely irreversible**.
  → risk of inefficient investment -stranded assets
- There is **learning** regarding future developments
  → inter-temporal resolution of uncertainty
- The planner can exert managerial flexibility
  → ‘Fit-and-forget’ vs. ‘Wait-and-see’.

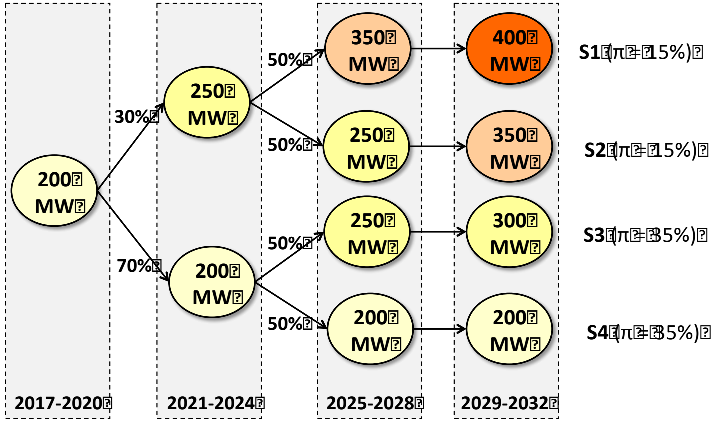
Planning-under-uncertainty optimisation frameworks are fundamental for identifying **openings for strategic action**

Motivating Example I

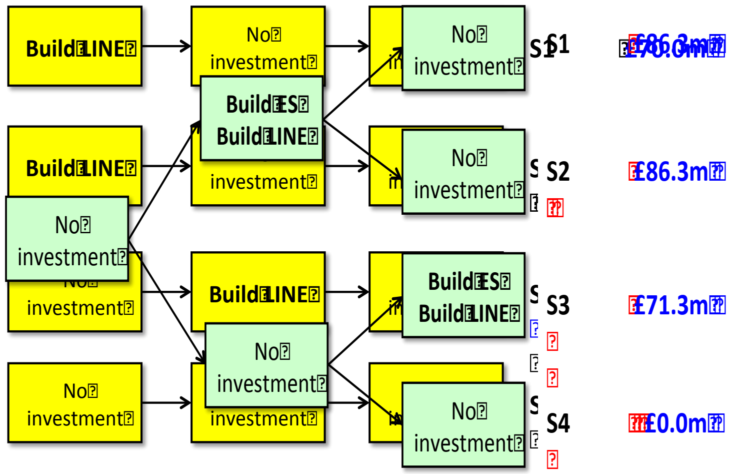
Network



Scenarios



Investment plan
(ignoring uncertainty)
(with uncertainty)



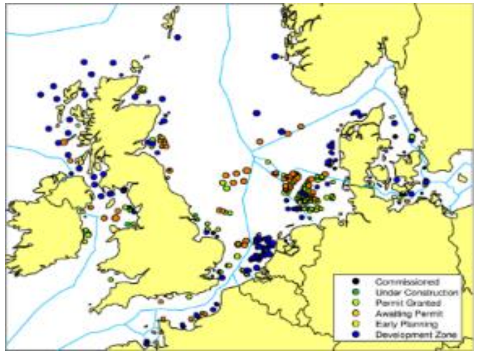
Consideration of uncertainty leads to radically different first-stage decisions!

G. Strbac et al. “Opportunities for Energy Storage: Assessing Whole-System Economic Benefits of Energy Storage in Future Electricity Systems”, IEEE Power and Energy Magazine, 2017.

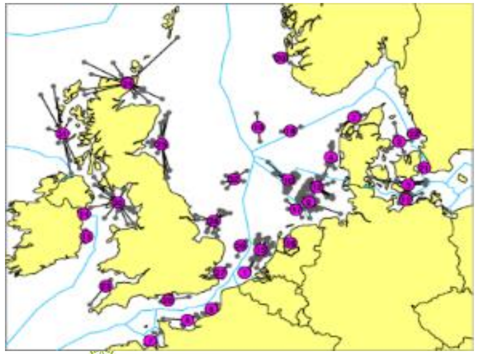
Motivating Example II – North Sea Grid

Transmission investment in North Seas countries (2020-2045) under **uncertainty** wrt future **offshore wind deployment.**

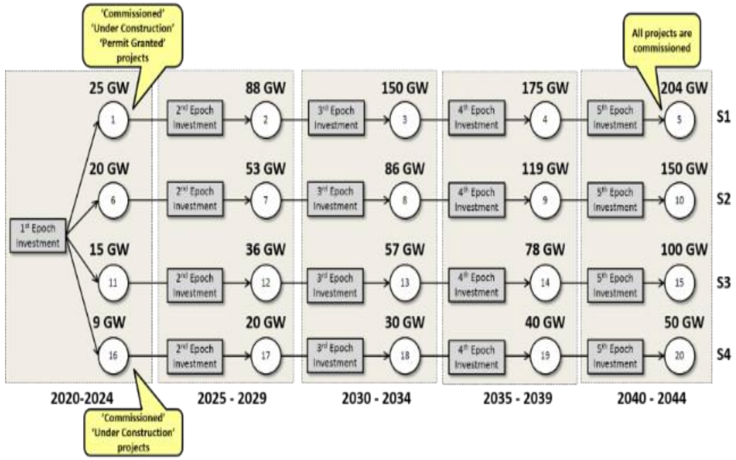
> 500 projects



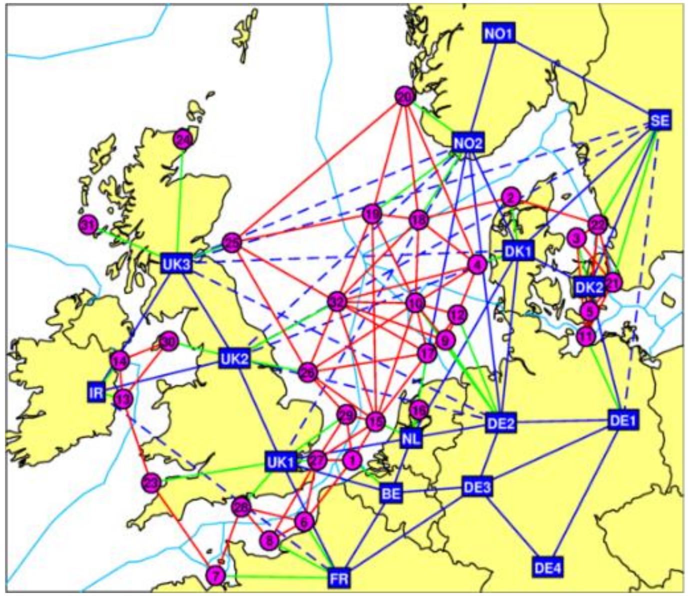
Project clustering



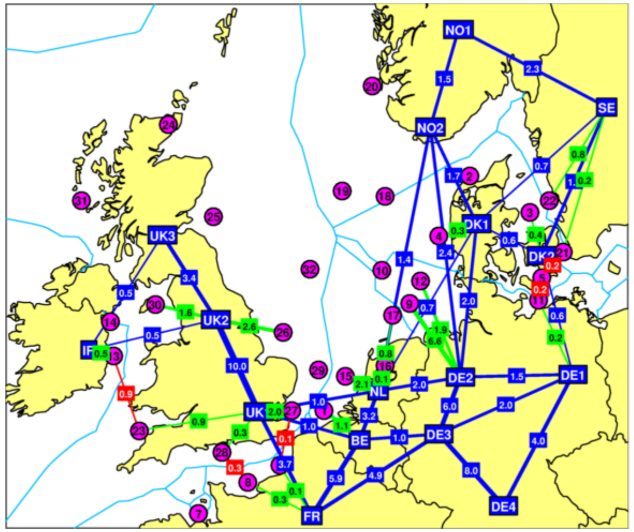
Multi-stage scenario tree



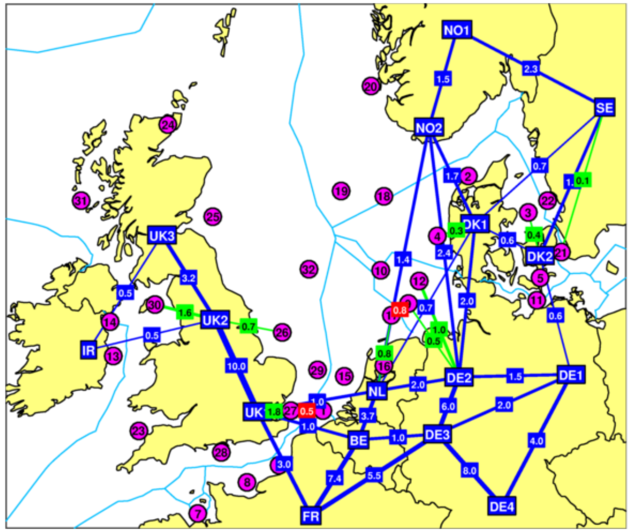
Candidate topologies



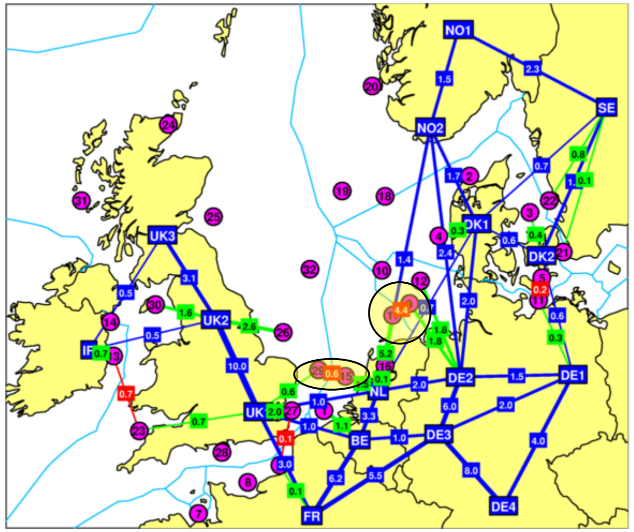
Motivating Example II – North Sea Grid



1st stage commitments -
High wind deployment scenario



1st stage commitments -
Low wind deployment scenario



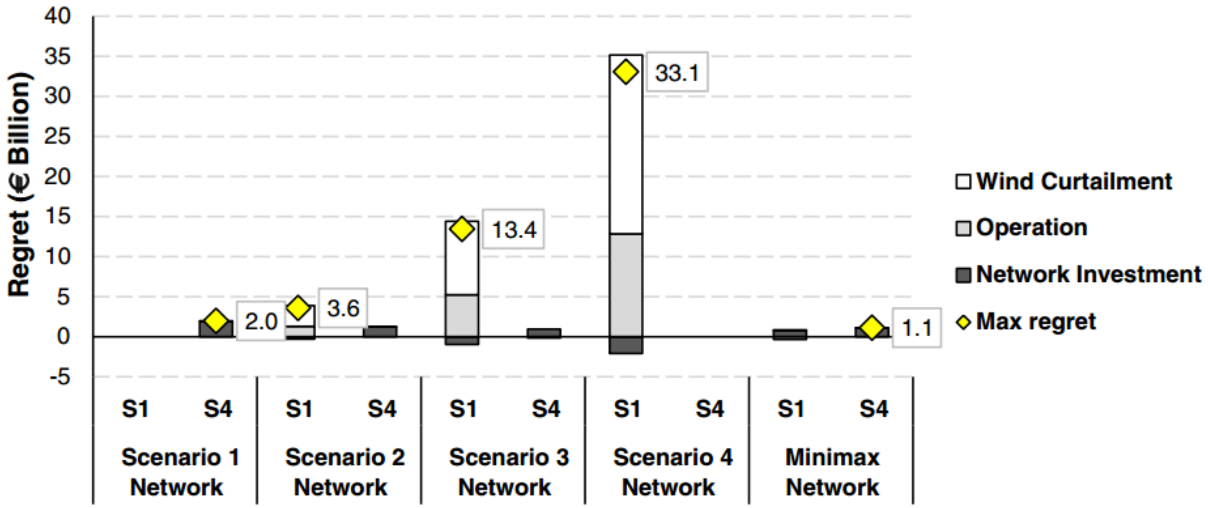
1st stage commitments -
Strategic planning

Previously "unseen" opportunities are uncovered

I. Konstantelos et al. "Coordination and uncertainty in strategic network investment: Case on the North Seas Grid", Energy Economics, 2017.

Motivating Example II – North Sea Grid

Adopting a deterministic view of the future can lead to:
- Over-investment
- Under-investment
- Disregard of flexible investment options



Model Features

- ❑ **Investment constraints**
  - New builds, reinforcements, FACTS, energy storage, DSR etc.
  - Build times
  - Asset age and projected decommissioning dates
- ❑ **Operational constraints:**
  - Centralised operation of assets
  - DC OPF (ex-post validated on AC)
- ❑ **Regulatory constraints:**
  - Carbon emission targets
  - Target network asset redundancy level for security (e.g. N-1)
  - Policy towards cross-border interconnections
- ❑ **Uncertainty modelling:**
  - Scenario trees

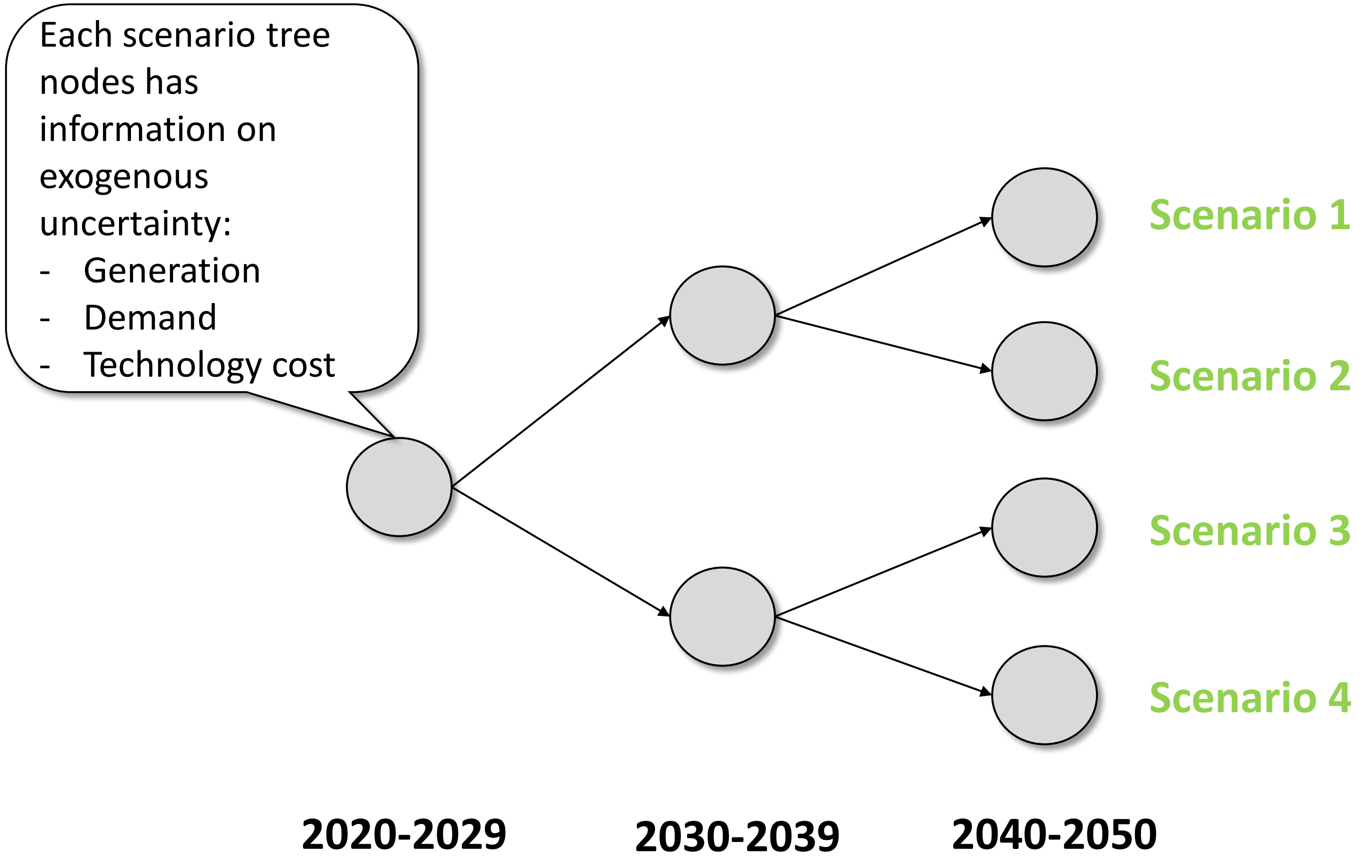
Europe-RE net model

Which uncertainties are modelled?

- Location, type and size of new **generators**
  (Focus on nukes, gas, coal, PV and offshore wind)

- Electric **demand** increase (electrification of heat + transport)

- Future **CAPEX** of technologies such as Energy storage



Model outputs

- Investment and operational cost per scenario, stage etc.
- Optimal network investment strategy
  - Line reinforcements
  - Energy Storage, DSR schemes, FACTs etc.
- All operational data:
  - Line flows
  - Cross-border trade volumes
  - Generation output levels/hours of operation
  - Use of Energy Storage, DSR etc.
  - CO_2 levels
- Revenue of all players:
  - TSOs (regulated/FTR-based revenue model)
  - Generators
  - DSR schemes, energy storage etc.

Further insights

- Insights can be obtained by comparing several studies :
  - **Assessing the impact of uncertainty:**
    1. Carry out deterministic studies for each of the scenarios and identify optimal investment actions.
    2. Subsequently, carry out stochastic studies to assess impact of particular sources and identify robust strategic actions.
  - **Assessing the value of new technologies:**
    1. Basecase: only conventional transmission reinforcements allowed.
    2. Progressive addition of new technologies to evaluate their net benefit and their complementarity

Discussion points

- Sources of uncertainty
  - Any other potential aspects?
- Data
  - Useful data sources on future scenario projections (national/EU-wide) ?
- Additional sensitivity analysis/potential uses

Thank you

Questions?