UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

SUPERGEN FLEXNet

Transmission Planning Under Uncertainty: A Stochastic Two-Stage Modelling Approach

Harry van der Weijde | EPRG, University of Cambridge | hv234@cam.ac.uk
Benjamin F. Hobbs | EPRG & Johns Hopkins University | bhobbs@jhu.edu

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Making networks fit for renewables …

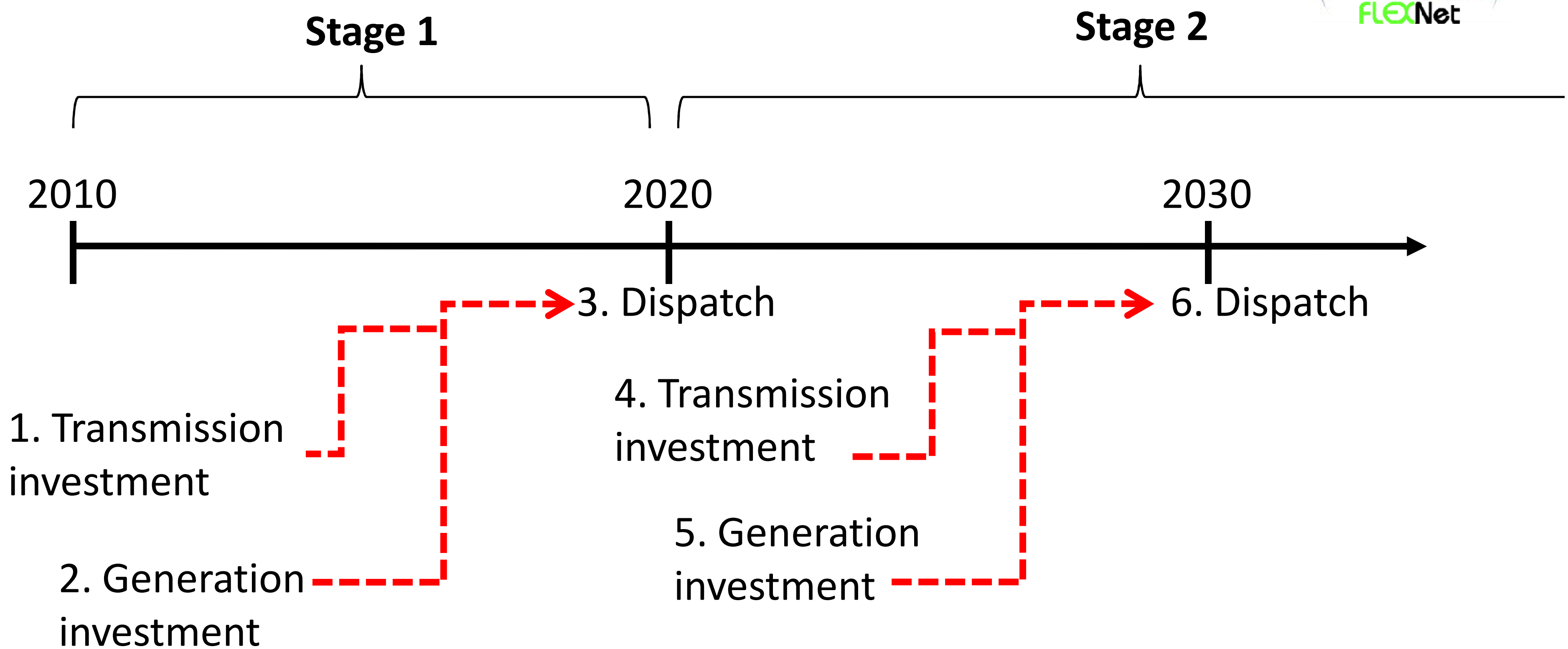
Overview

- The problem
- Our model
  - How it works
  - Data it needs
  - Data sources + assumptions
- Some results
- Our conclusions

The problem

- Transmission planning
  - The generation market responds: **multi-level** game
  - Decisions can be postponed: **multi-stage** game
  - Uncertainties: **stochastic** problem
- Important questions:
  - Optimal strategy under uncertainty?
  - Value of information? (EVPI)
  - Cost of ignoring uncertainty? (ECIU)
  - Option value of being able to postpone?
- **Deterministic planning cannot answer these!**

Our model: timeline



Objective: min total costs (investment + generation) s.t. power flow constraints, wind availability, build limits, renewables targets

Some assumptions

- Alignment of generation and transmission objectives
  - e.g., nodal pricing + perfect competition

Some assumptions (cont'd)

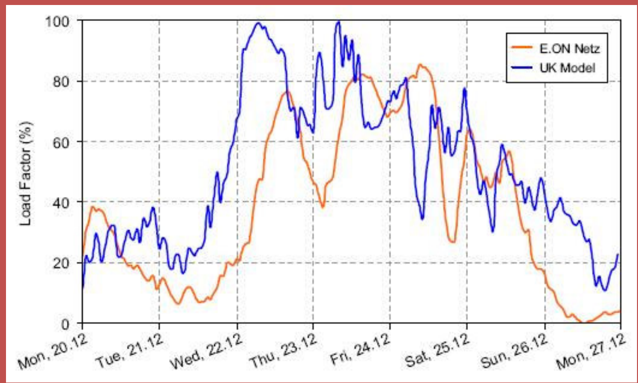
- Generation
  - Constant variable costs
  - No start-up costs, min run levels, 'lumpy investment'
  - No ramping constraints
- Transmission: constant flow limits
- Demand:
  - No short-term demand flexibility, demand-side management
- Renewables targets met in most efficient way
- No new storage

Data necessary

regions
+ transmission
constraints

generator types
+ current capacities
+ maximum build limits
+ costs

wind output and demand
time series (1 year)



investment alternatives

scenarios
(2020, 2030) &
probabilities:
generation costs
(incl. carbon price),
transmission
investment costs,
demand,
renewable targets,
nuclear feasibility

Data sources

- Wind data: Neuhoff et al. (2006)
- Demand data: National Grid
- Maximum build limits: Various
- Regions + transmission constraints: NG
- Investment alternatives: ENSG
- Generation costs: NEA and IEA (2005), US DOE, own calculations
- Scenarios: Various (Discovery, LENS, Redpoint, etc.)

Alternatives

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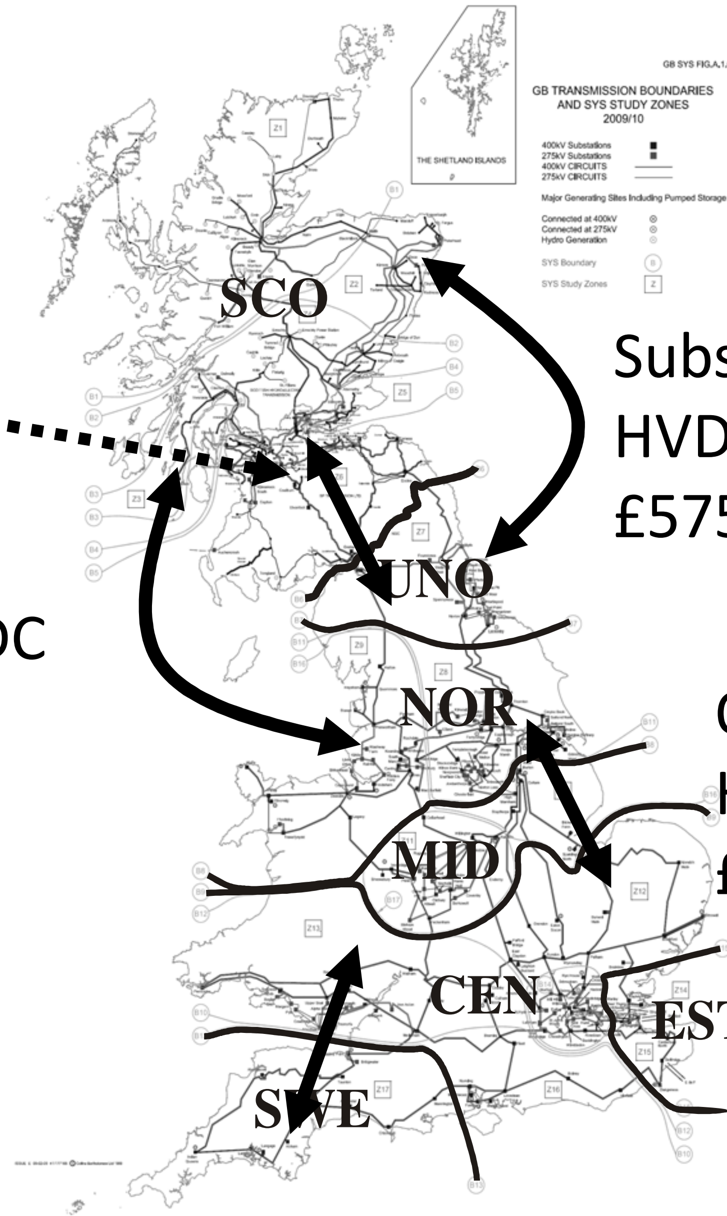
Various new/ upgrades £260M

Subsea HVDC £575M

Subsea HVDC £575M

Onshore HVDC £410M

Various new/ upgrades £410M



Scenarios

	Gen. inv. cost	Var. gen cost	Trans. inv. cost	Demand	CO_2 price	Others
Status Quo		CCGT/OCGT/DG: +		+	+/-	No RT
Low cost DG	DG: --	CCGT/OCGT: - DG: --		+	++	RT: + Nuclear replacement only
Low Cost Large Scale Green	Renewables : --	CCGT/OCGT/DG: ++		--	+++	RT: +++
Low Cost Conventional	Conventional: -	CCGT/OCGT/DG: -		++	+	No RT
Paralysis	All except offshore: +++	CCGT/OCGT/DG: +	Onshore: +++ Others +	++	++	RT: + Nuclear replacement only
Techno+	All : -	CCGT/OCGT/DG: +	-	++	++	RT: ++

Some results

Disclaimer: the following results are preliminary and based on restrictive assumptions.

They cannot be used to evaluate proposed transmission investments.

Optimal stochastic solution

Onshore wind

Offshore wind

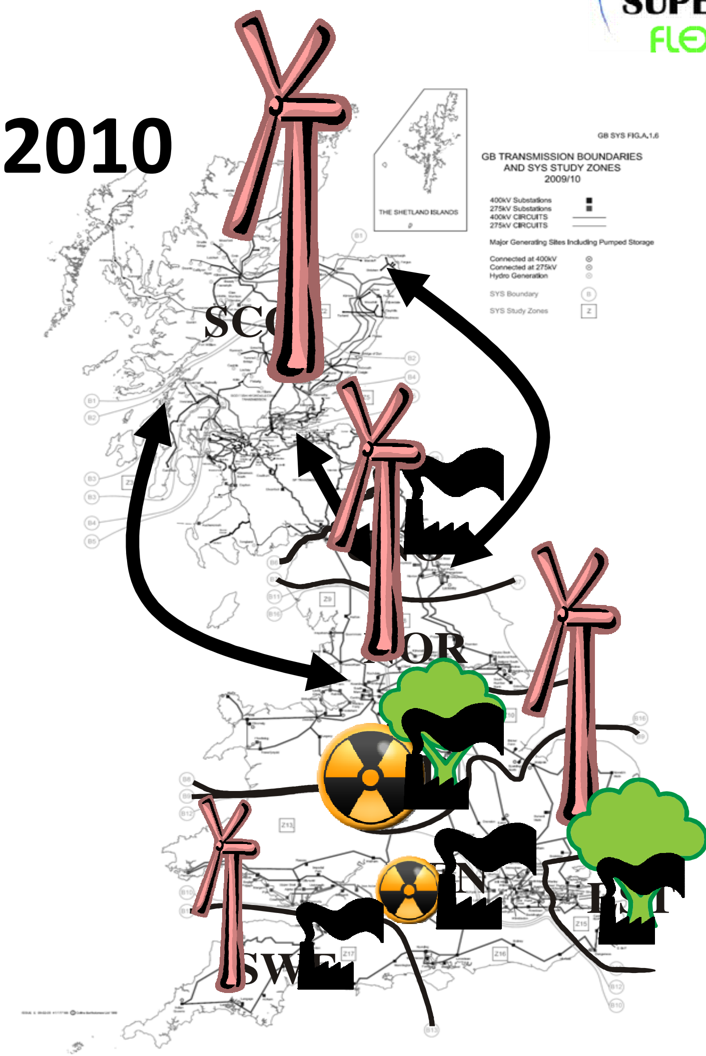
Nuclear

Biomass

CC

GT

2010



Value of perfect information

- How much average savings if we knew which scenario would happen?

1. Solve stochastic model
2. Solve deterministic model for each scenario
3. Compare objectives (1) and (2)

Cost of ignoring uncertainty

- How much would costs go up if we naively plan for one scenario but other scenarios can happen?

1. Solve stochastic model
2. Solve naïve (deterministic) model for each scenario
3. Solve stochastic model, imposing first-stage transmission decisions from step 1
4. Compare objectives (1) and (3)

Cost of ignoring uncertainty

Scenario planned for	ECIU (Transmission) *(Present worth)*
Status Quo	£392M
Low Cost DG	£0
Low Cost Large Scale Green	£0
Low Cost Conventional	£392M
Paralysis	£134M
Techno+	£0
Average	£153M = 0.11% of expected costs (stochastic solution)

Option value of waiting

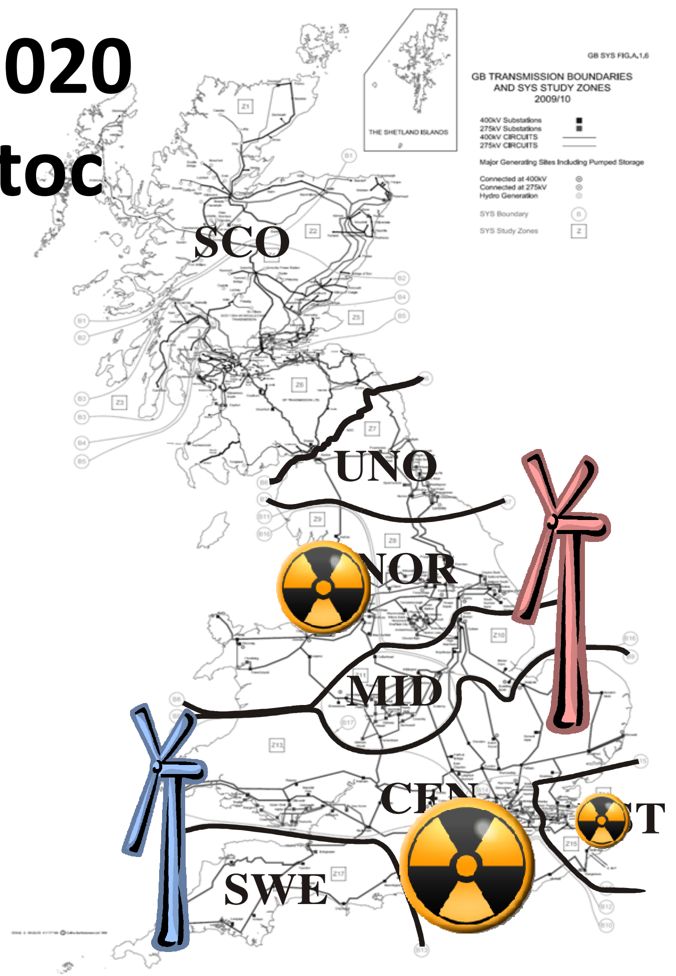
- How much would costs go up if we had to make all decisions now?

1. Solve stochastic model
2. Solve stochastic model, imposing same transmission expansion plan for all scenarios
3. Compare objectives (1) and (2)

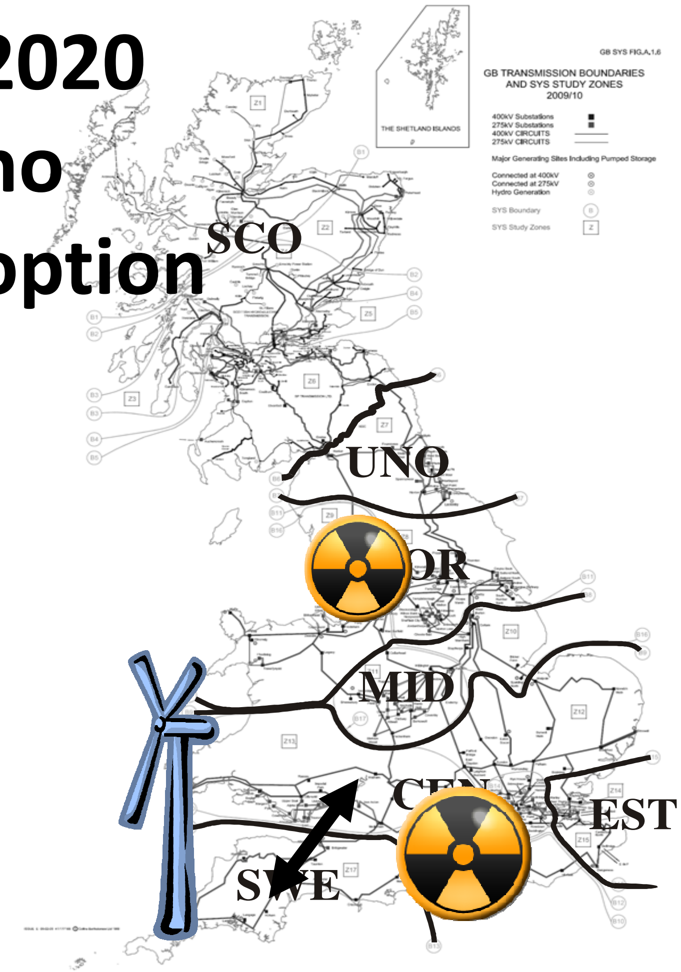
Option value of waiting

Example: Techno+

2020
stoc



2020
no
option



Option value of waiting

- Option value (transmission only):

  = £71M present worth= 0.05% of total costs (stochastic)

Conclusions

- For transmission planning:
  - Ignoring risk has quantifiable economic consequences
  - Option values can be significant
  - Approach useful for policy/planning questions
- Future work
  - Improve parameterisation
  - Ramping constraints
  - Demand response
  - Bi-level formulation