House of Energy Markets & Finance

Probabilistic methodology for adequacy assessment under uncertainty for a multi-region system

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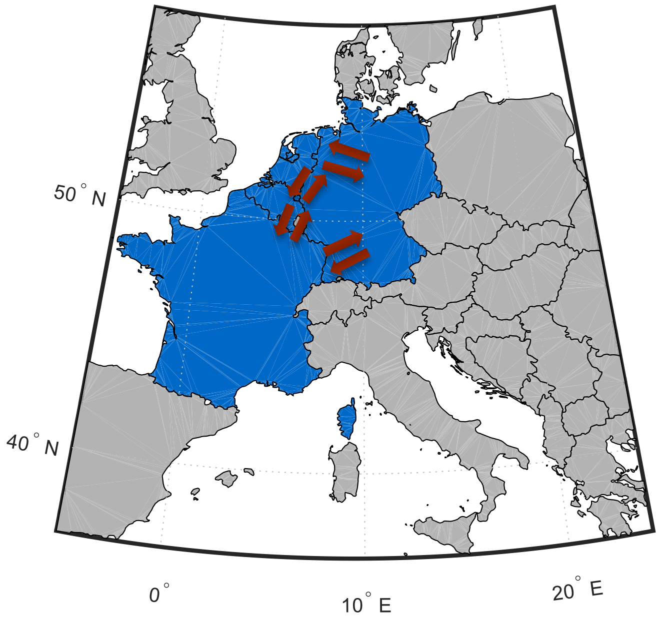
Motivation

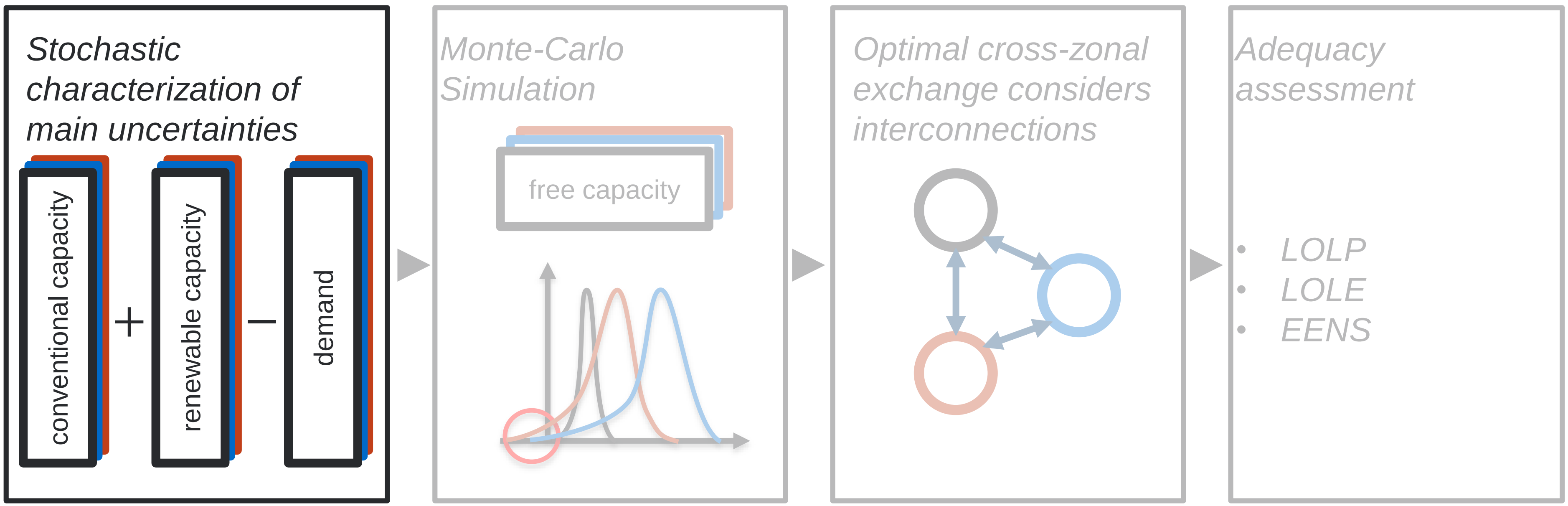
- Reliability monitoring predominantly national
- Current developments
  - growing shares of intermittent electricity generation from RES
  - increasing uncertainties, need for (conventional) back-up capacity
  - proceeding integration of electricity markets
  - increasing electricity exchange btw. countries
- Idea: monitoring reliability within a multi-national framework
- Question: does it matter for assessing adequacy, and if yes, how much?



Agenda

Methodology overview

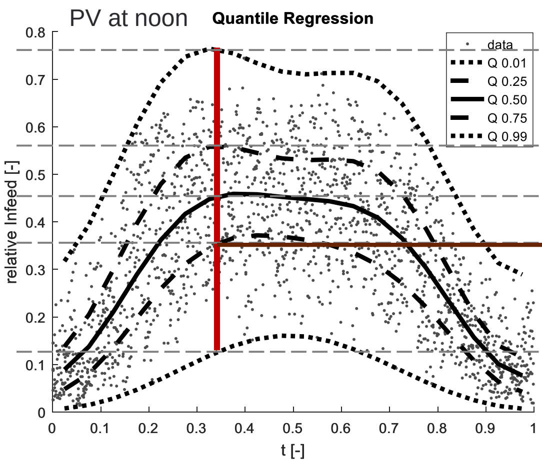
Methodology

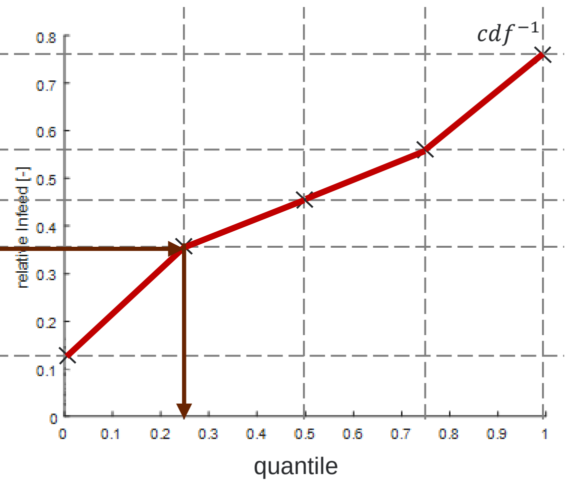


I. Stochastic characterisation

Methodology

Quantile regression



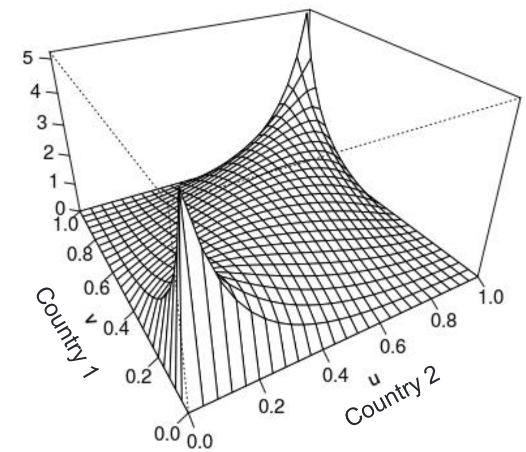


- Estimation of marginal conditional (multivariate) distributions

$$g_{h,i,p}(t) = \alpha_{0|h,i,p} + \alpha_{1|h,r,p} \cdot \cos\left(2\pi \cdot t + \beta_{1|h,i,p}\right) + \alpha_{2|h,i,p} \cdot \cos\left(4\pi \cdot t + \beta_{2|h,i,p}\right)$$

- Transformation to uniformly distributed values

Gaussian copula



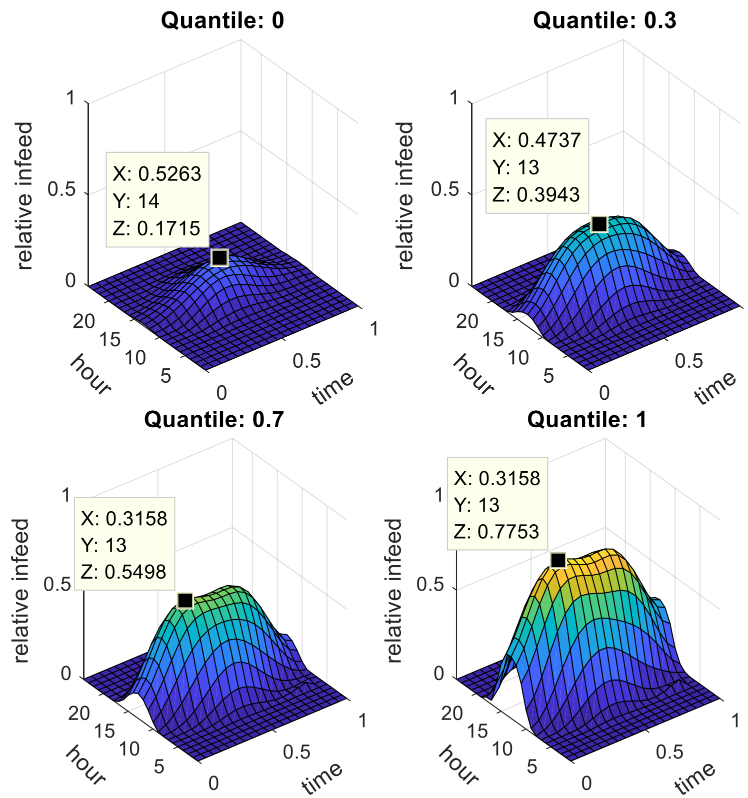
Source: http://shiny.hydrology.ruhr-uni-bochum.de:3838/

- Dependencies from marginal distributions

I. Stochastic characterisation: exemplary results

Methodology

Quantile regression for PV in Germany

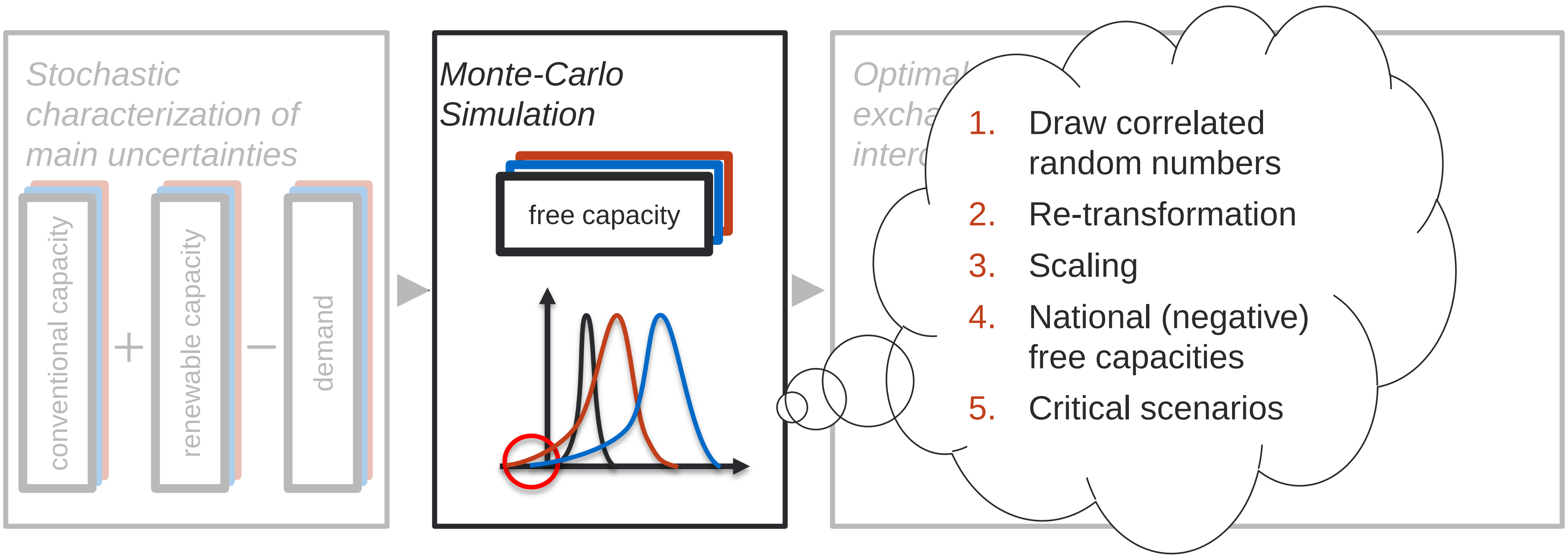


Copula correlation matrix (wind in BE, DE, FR, NL)

	BE	DE	FR	NL
BE	1	0.5422	0.7165	0.674
DE	0.5422	1	0.3935	0.6446
FR	0.7165	0.3935	1	0.4404
NL	0.674	0.6446	0.4404	1

II. Monte-Carlo Simulation

Methodology



III. Optimal cross-zonal exchange

Stochastic characterizati
main uncerta

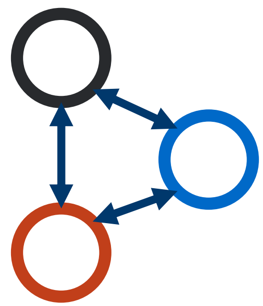
conventional capacity

+

Optimisation problem

- Min negative remaining cap
- S.t.
  - National balances (neg. remaining cap)
  - Transmission capacity restrictions (NTC, flow-based)

Optimal cross-zonal exchange considers interconnections



Adequacy assessment

- *LOLP*
- *LOLE*
- *EENS*

IV. Assessment indicators

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Methodology

- Assessment based on

  From step II
  - Free capacity
  - Number of critical scenarios

  From step III
  - Remaining free capacity
  - Number of remaining critical scenarios
  - Limitations on the transmission lines/ critical branches

- Adequacy indicators

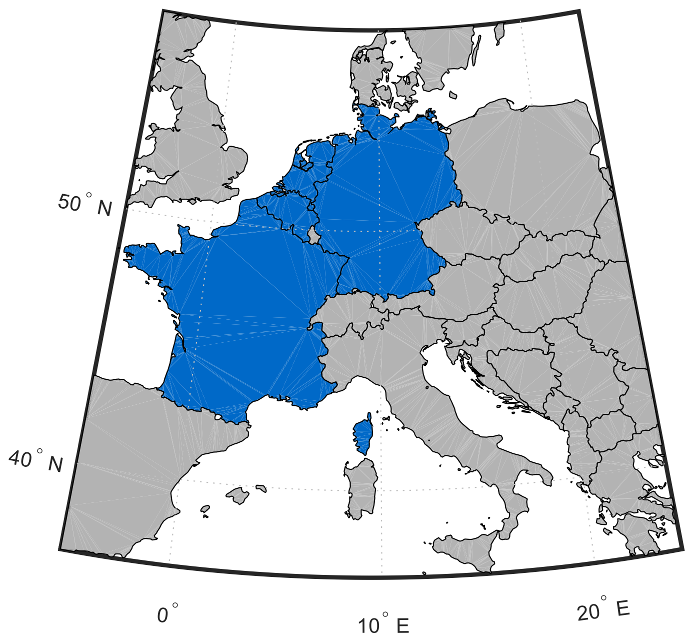
  Probability of occurrence
  - Loss of load probability
  - Loss of load expectation

  Extent
  - Expected energy not served
  - etc.

Adequacy assessment

- *LOLP*
- *LOLE*
- *EENS*
- *etc.*

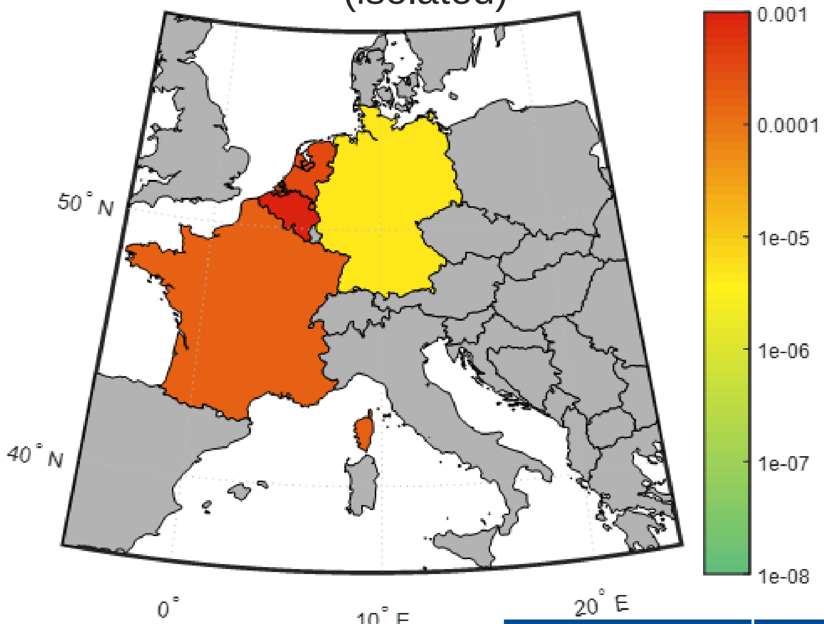
Application



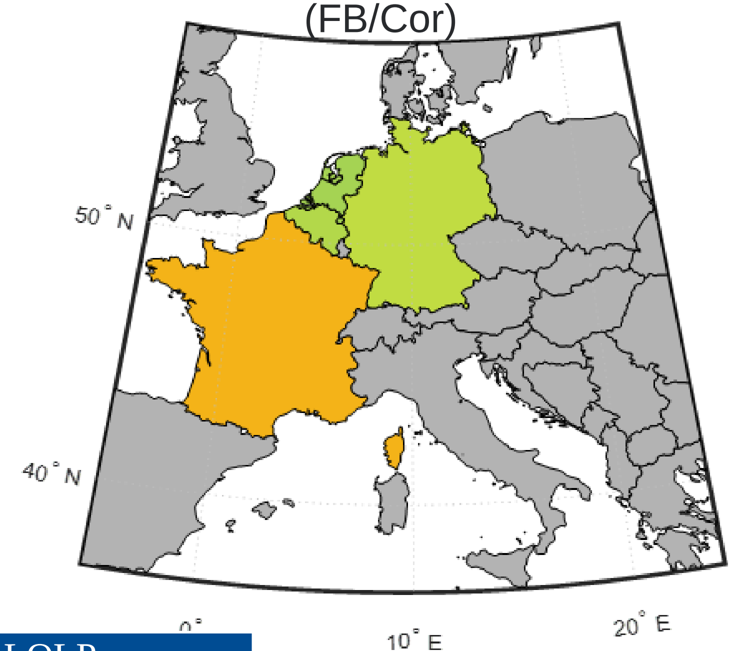
- Scope
  - Countries: DE, BE, NL, FR
  - Year: 2025
- Data
  - Characterisation: historical time series
  - Analysis: G+T capacities, demand, PTDF matrix
- Scenarios
  - Isolated: separate countries interconnection
  - Interconnected: FBMC-based, spatial interdependencies
  - Sensitivity: spatial interdependencies
  - Sensitivity: seasonal availability of conventional Gcap

Application: Analysis of security of supply

Isolated countries (isolated)



Interconnected countries (FB/Cor)



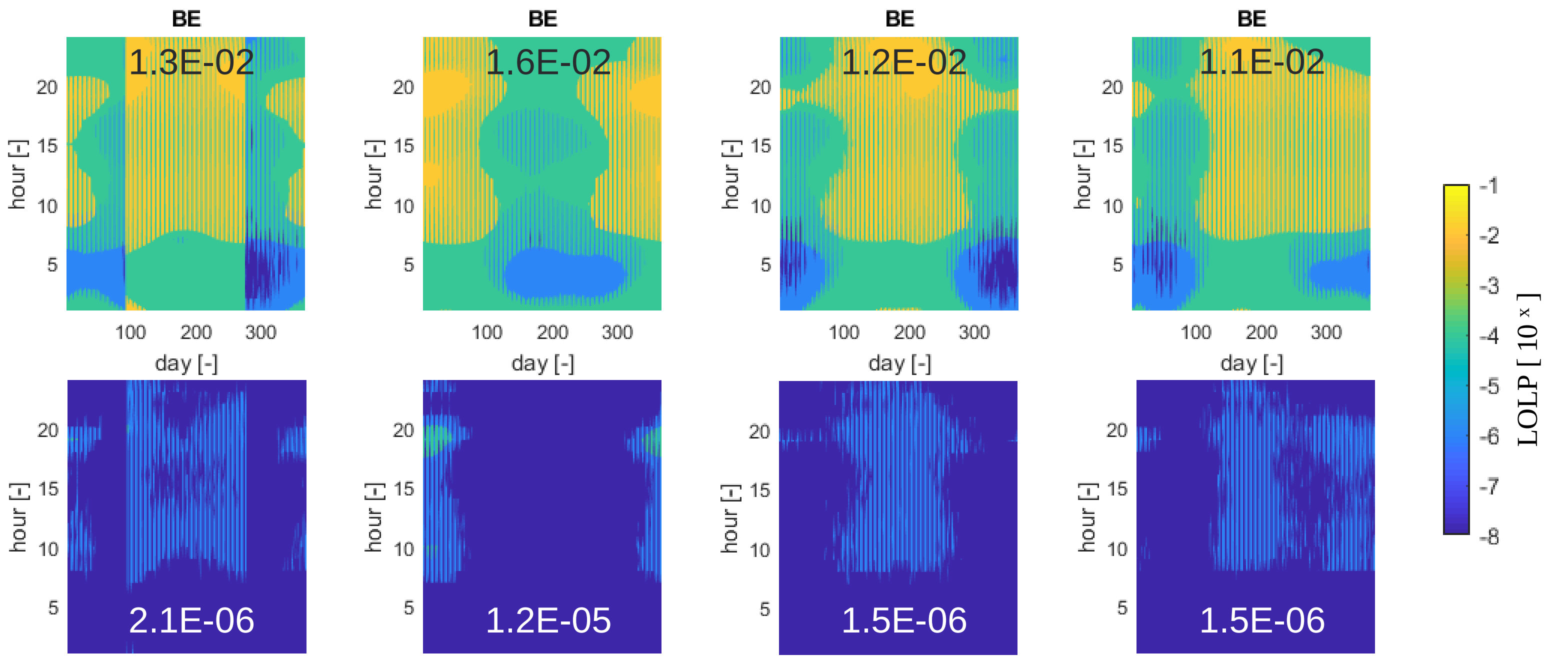
	Mean LOLP	
	isolated	Connected
BE	1.3E-02	2.1E-06
DE	4.3E-06	2.8E-07
FR	7.9E-05	7.5E-06
NL	3.3E-04	2.2E-07
mean	3.4E-03	2.5E-06

Application: Analysis of security of supply

Sensitivities: seasonal availability of conventional generation capacity (LOLP)

Isolated countries

Interconnected countries



Step function

No seasonal pattern

trigonometric

optimised

Conclusions and further research

- Conclusions
  - Probabilistic methodology for adequacy assessment in multi-national framework
  - Compensation of shortfalls through other countries → reduces LOLP significantly
  - Sensitivity: spatially interdependent uncertainties → decrease system adequacy
  - Sensitivity: seasonal patterns of conventional availability → severe impact → coordinated revision scheduling
- Further research
  - Temporal interdependencies
  - Impact of shut-down / phase-out of single technologies

Room for Q&A

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III. Optimal cross-zonal exchange

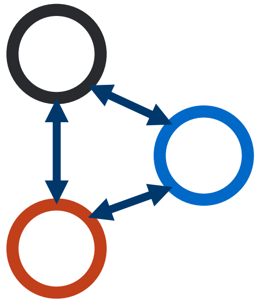
Stochastic charact… main u…

conventional capacity

Optimisation problem

- $\min z = \sum_i L^{rem}_{neg,i}$
- S.t.
  - $L^{rem}_{pos,i} - L^{rem}_{neg,i} + NEX_i^{NFB} + NEX_i^{FB} = L_i \quad for\ \forall i$
  - $\sum_{c \in NFB_i^{ex}} f_c - (1 - \eta_{trans}) \cdot \sum_{c \in NFB_i^{im}} f_c \leq NEX_i^{NFB}$
    $f_c \leq K_c$
  - $\sum_k PTDF_{c,k} \cdot NEX_k^{FB} \leq K_c$

Optimal cross-zonal exchange considers interconnections



Adequacy assessment

- *LOLP*
- *LOLE*
- *EENS*

Application: Analysis of security of supply

Sensitivities spatial interdependencies and FBMC

	Mean LOLP				
	isolated	interconnected			
					FB/Cor
BE	1.3E-02				2.1E-06
DE	4.3E-06				2.8E-07
FR	7.9E-05				7.5E-06
NL	3.3E-04				2.2E-07
mean	3.4E-03				2.5E-06

	Relative EENS				
	isolated	interconnected			
					FB/Cor
BE	8.3E-04				7.8E-08
DE	6.9E-08				6.5E-09
FR	3.3E-06				2.7E-07
NL	1.1E-05				5.2E-09
mean	2.1E-04				9.1E-08