

Modelling long- term energy pathways with high shares of variable renewable energy sources

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based on work with Birgit Fais and Ed Sharp

- The UK TIMES (UKTM) model is a linear optimization bottom-up technology-rich energy system model
- Runs from 2010 to 2050
- 16 time slices: 4 seasons and 4 intraday (day, evening, late evening, night)
- One region representing the whole of the UK
- VRE represented as technologies with low availability factors with limited variability between time slices

VRE and demand vary in time and space

➤ Not sufficient spatial and temporal resolution to represent

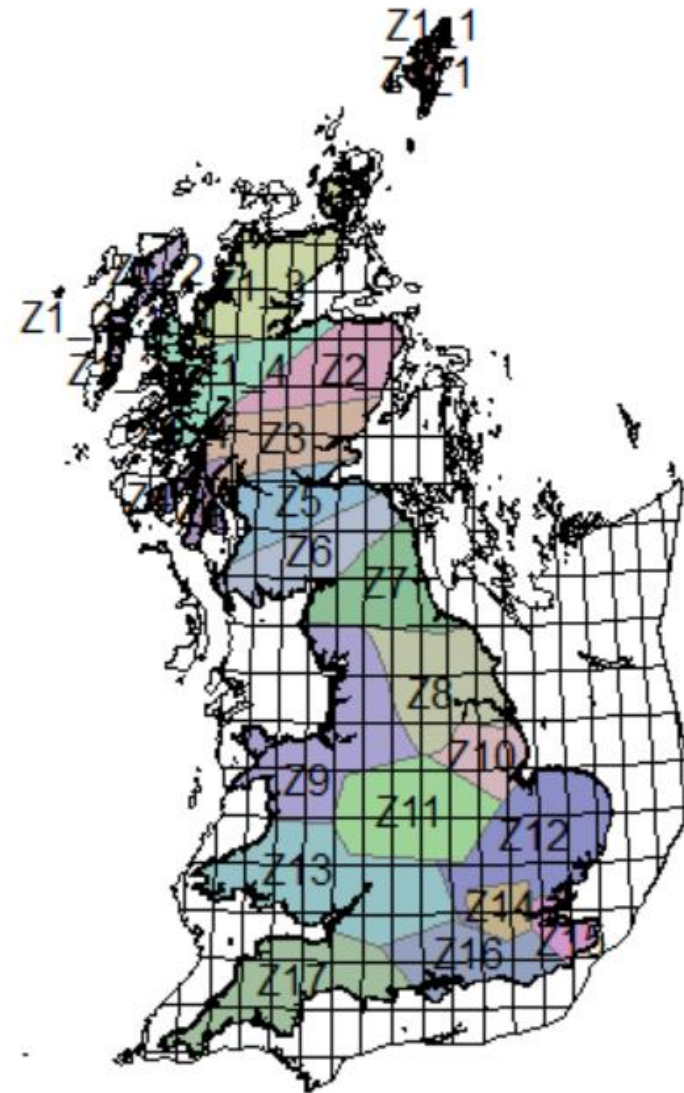
1. Renewable generation
2. Demand
3. Flexible generation
4. Storage
5. Transmission extension
- + Their interaction

➤ Modeling of single weather years does not capture the full variability of weather conditions

How well does UKTM model the integration of variable renewable energy sources?

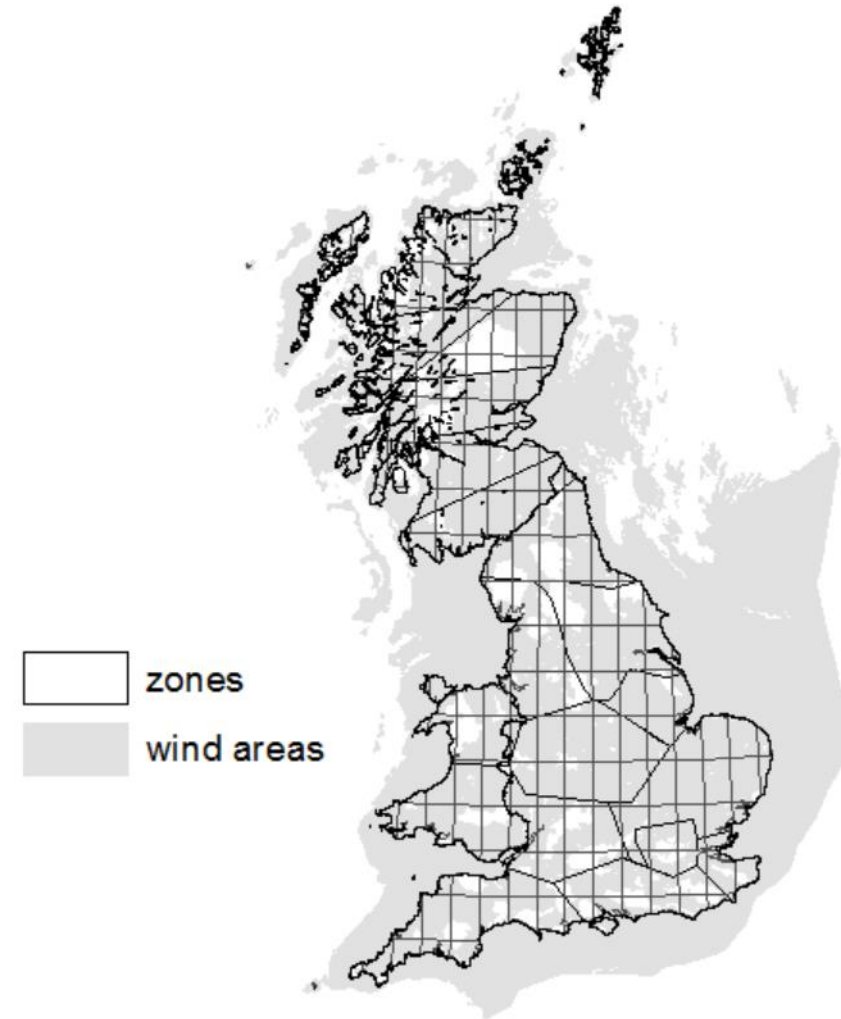
- High spatial and temporal resolution electricity system model highRES:
 - Complements UKTM to find cost-effective, flexible and robust low carbon electricity pathways
 - Integration options are network reinforcement (spatial diversification), energy storage, flexible generation
- Objective function: minimise power system costs to meet hourly demand subject to constraints
 - Technical constraints: ramping, minimum & maximum generation
 - Storage constraints
 - Transmission constraints
- Output: Total system costs, electricity price, power plants usage rates, emissions, renewable curtailment, location of generations and integration options
- Strong point: good representation of VRE

- VRE generation at grid level ($0.5^\circ \times 0.5^\circ$ or about 50km x35 km)
- VRE aggregated to model zones
- Demand- Supply balancing at zonal level

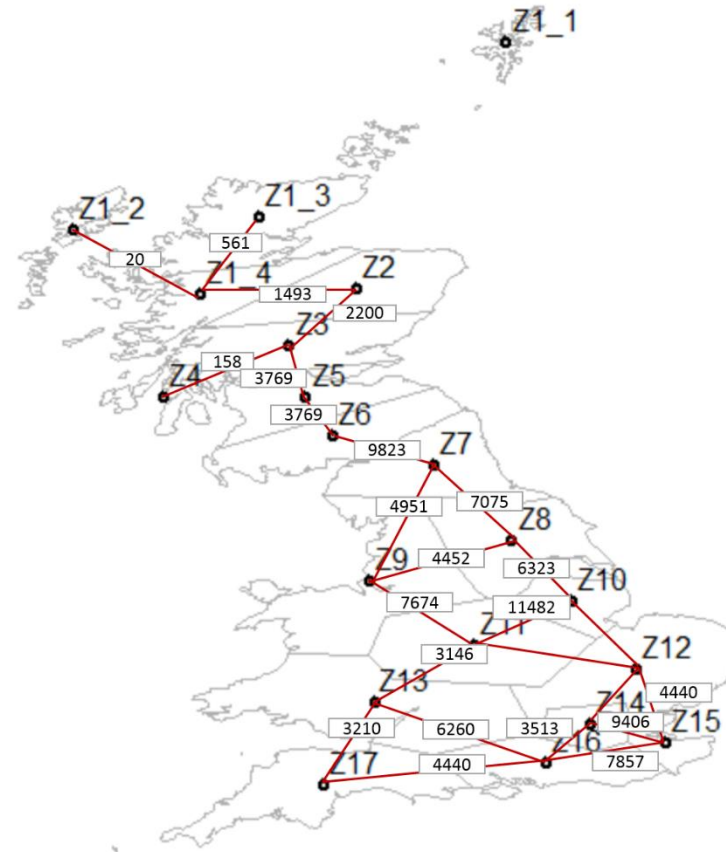


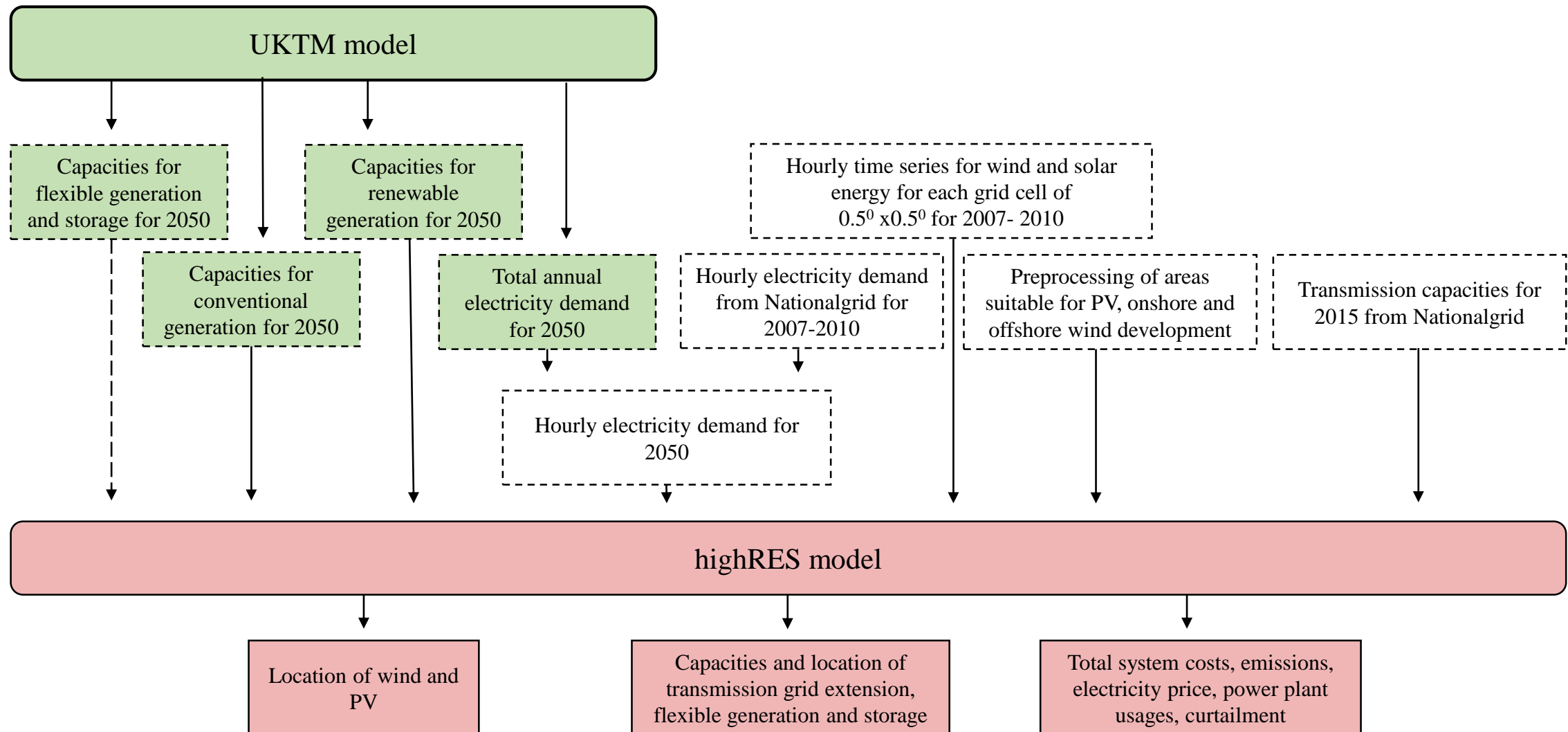
- VRE generation at grid level
 - Wind energy: hourly data from NCEP-CFSR climate reanalysis model
 - Solar energy: hourly value from PV-GIS

- Resource specific constraints to constrain the potential



- Demand Supply Matching at Zonal Level
 - Zones and demand shares based on National Grid
 - Simplified grid connecting the zones and enabling demand-supply balancing between zones





UKTM
NO CCS
scenario

Solar 44.45 GW
Wind offshore 38.83 GW
Wind onshore 32.48 GW
Nuclear 34.2
Biomass 6.8 GW
Geothermal 0.5 GW
Hydro 1.64 GW

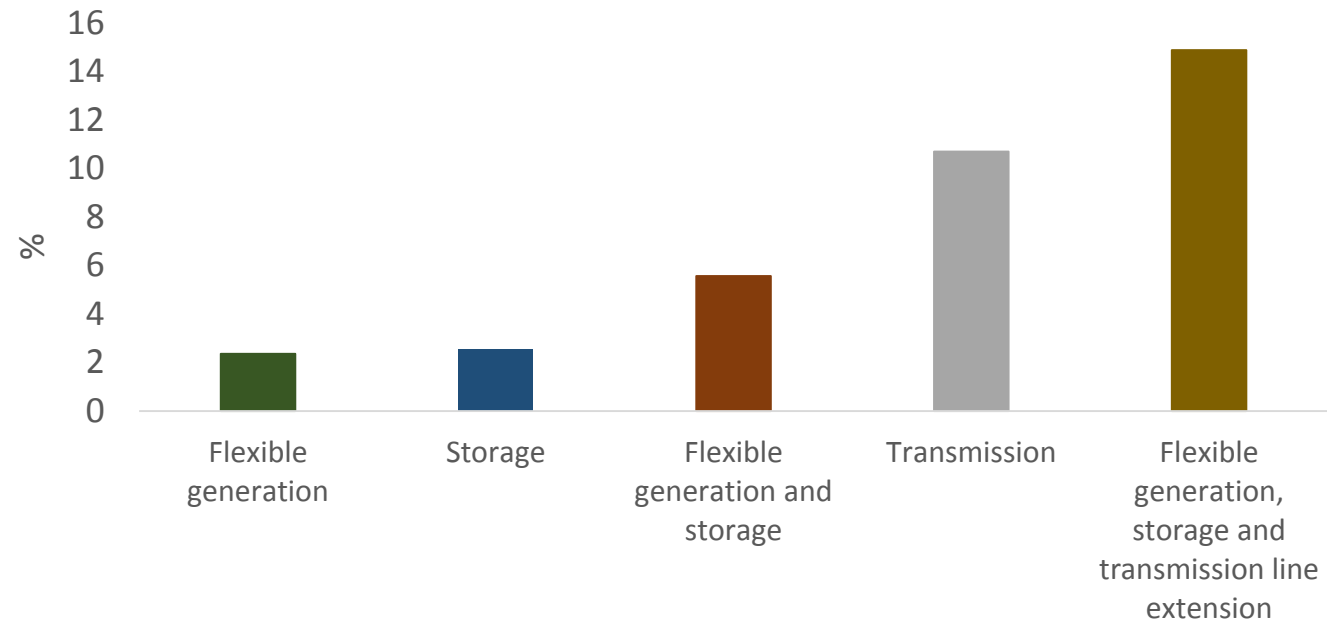
Flexible generation: 58.29 GW
Storage: 2.54 GW

24 highRES runs:

1. All capacities fixed to UKTM values
2. Flexible generation free
3. Storage free
4. Flexible generation and storage free
5. Transmission free
6. All flexible options free

for 2007- 2010, one year at a time

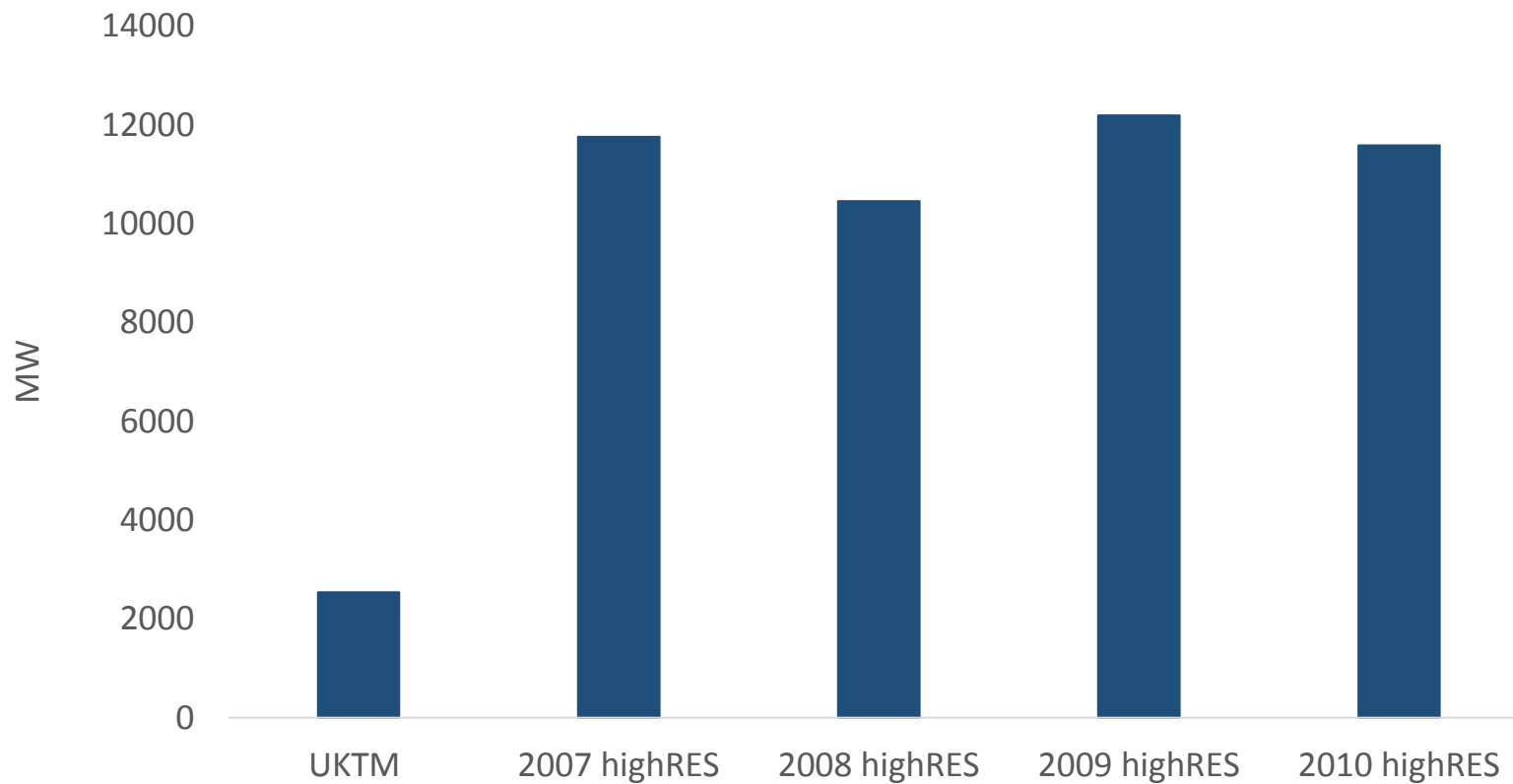
Reduction in annual total system costs for 2009 compared to a run with UKTM fixed capacities



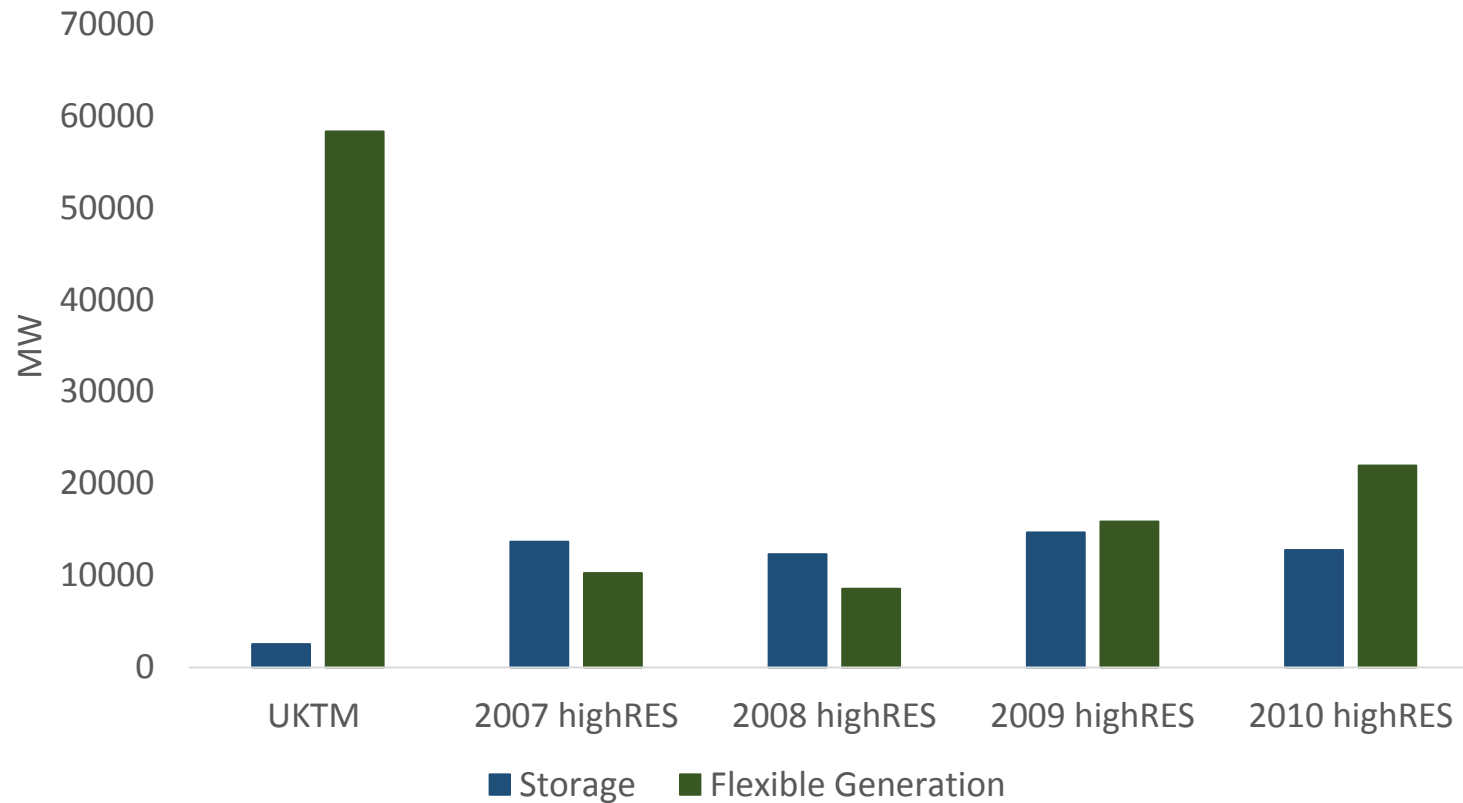
Installed capacity of flexible generation, all other capacities fixed to UKTM values



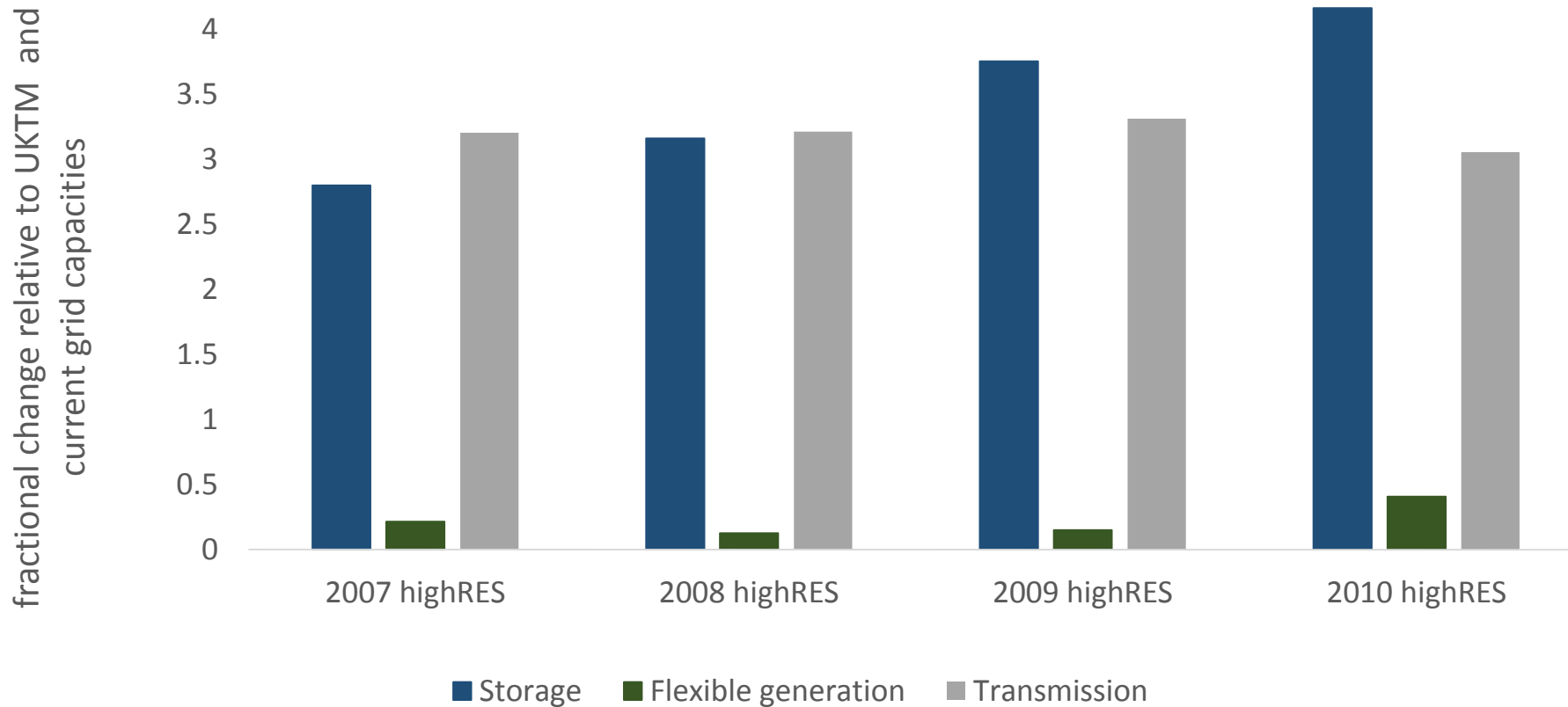
Installed capacity of storage, all other capacities fixed to UKTM values



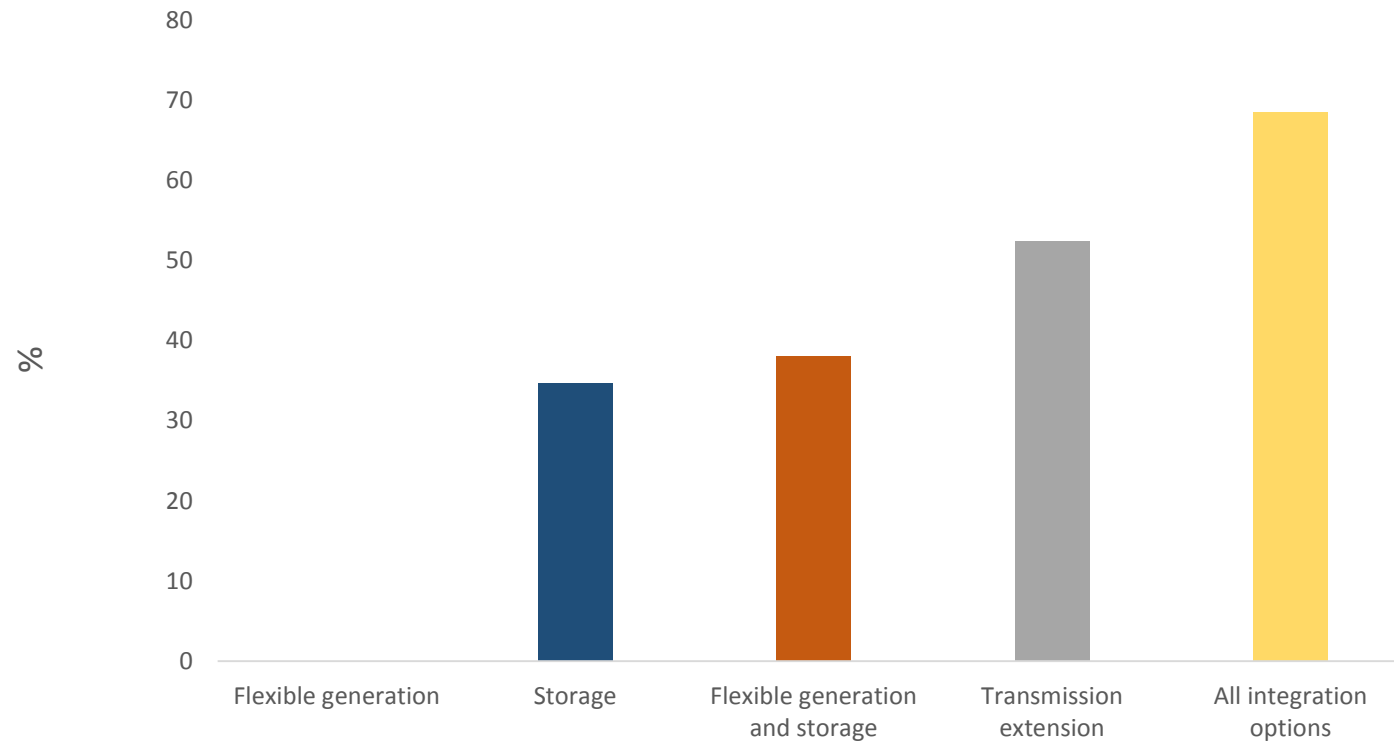
Installed capacity of flexible generation and storage, everything else fixed



highRES optimises all VRE integration options (flexible generation, storage, transmission)



Reduction in curtailment for 2007 compared to the to the UKTM fixed capacity run



- UKTM overestimates flexible generation and underestimates storage
- Large benefits of combining different integration options
- Using different weather years is important
- Grid extension is the most cost- effective integration option allowing to take advantage of the different output and timing of production of VRE

- Run with more weather years
- Improve demand representation
- Include interconnection and DSR
- Feedback to UTKM to improve representation of VRE



Thank you !



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