wholeSEM

Imperial College London

UCL

wholeSEM Top-down Integration Project:

Accounting for Impact of Flexibility on System Integration of Variable Renewables in Low-Resolution Models

Marko Aunedi (Imperial College London)

Peihao Li (UCL)

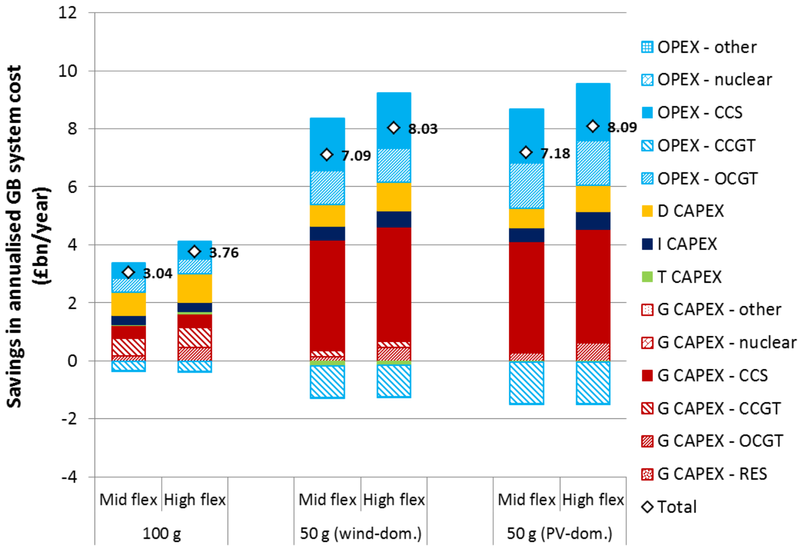
EPSRC
Pioneering research and skills

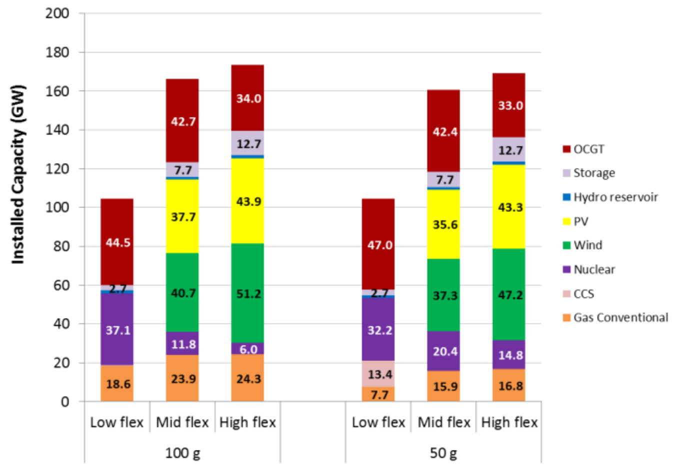
wholeSEM 4th Annual Conference

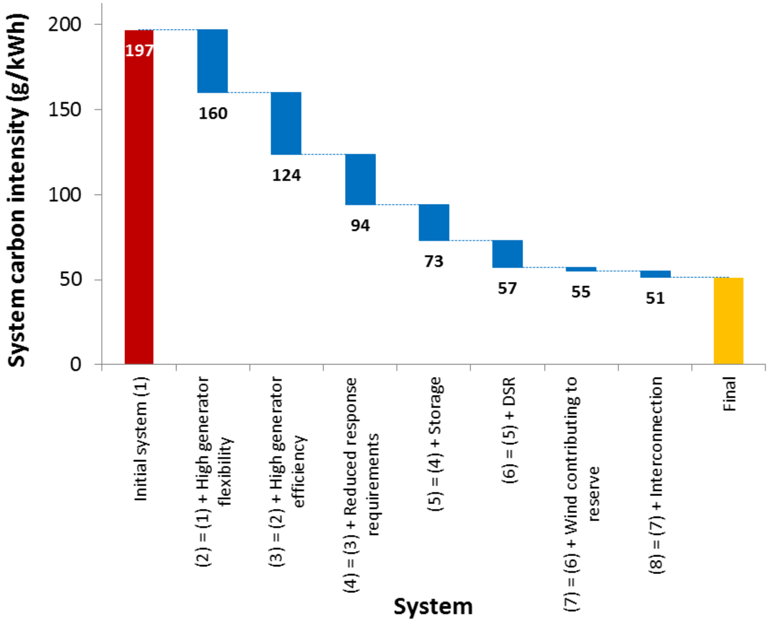
3-4 July 2017

Why flexibility matters?

- Previous studies (CCC, BEIS, Carbon Trust, NIC…) have shown that **flexibility is critical** for cost-effective integration of low-carbon technologies, in particular variable renewables (VRE)
  - Flexibility includes DSR, energy storage, network solution and flexible generation
- **High-resolution** modelling necessary to capture full implications of flexibility for VRE integration
- Multi-vector long-term energy system models often work with low resolution
- Hence, an approach to **link high and low-resolution models** is proposed to consider the impact of flexibility on system integration of VRE in long-term energy system planning



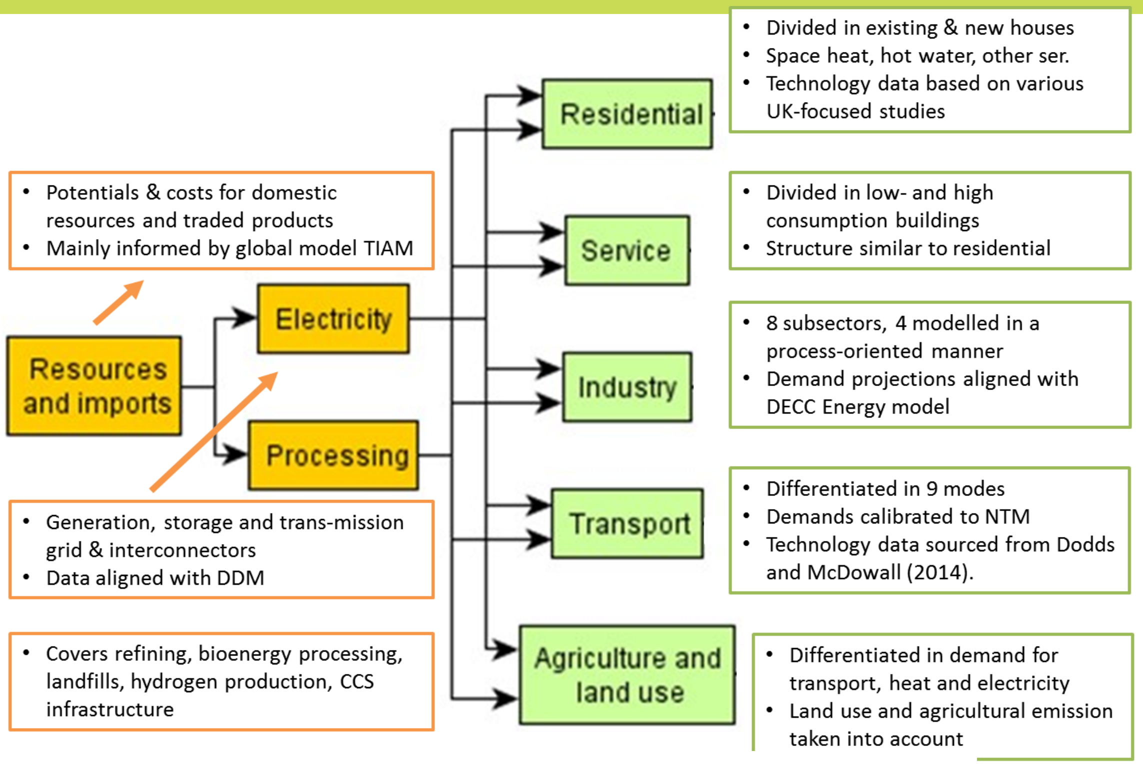




- ***How does the variability of RES generation affect its economic attractiveness?***
- ***What is the role of flexible technologies?***

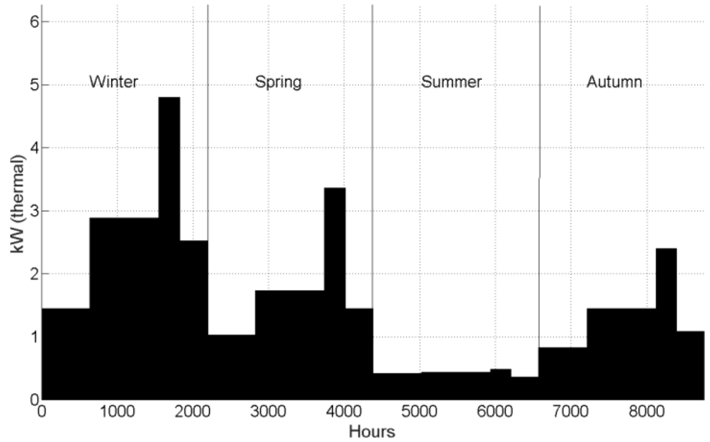
UKTM – The UK TIMES Model

- Developed by UCL Energy Institute
- Whole UK energy system
- Technology-rich
- Least-cost model
- Coarse spatial and temporal resolutions
  - National scale, 16 time-slices (4 slots in 4 representative days)
- Adopted by BEIS for policy making
  - 5th Carbon Budget
  - Emissions reduction plan



Key input data
- System configuration
- Resource supply curves
- Energy service demands
- Technology characterisation
- Constraints

Key outputs
- Total and annual energy system costs
- Primary & final energy - by sector / fuel
- GHG emissions; marginal emissions prices
- Im-/Exports & domestic production of fuels
- Electricity generation– by fuel / technology
- End-use technologies and fuel use
- Use of conservation, efficiency



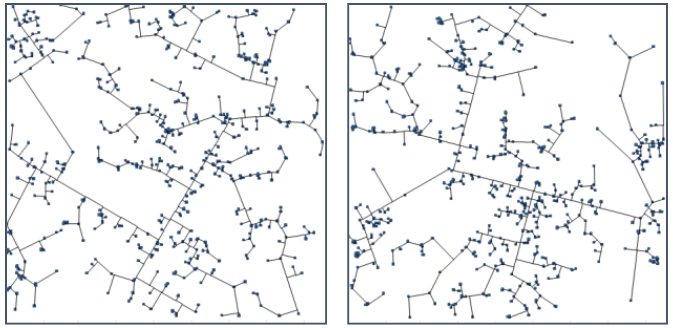
Time and Location effects

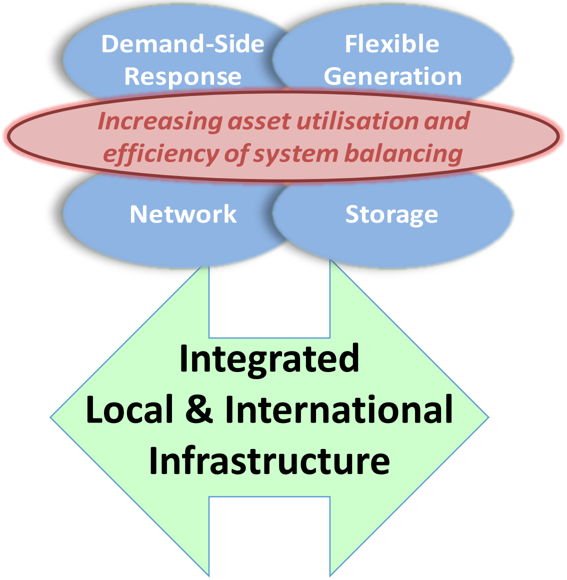
Imperial College London

UCL

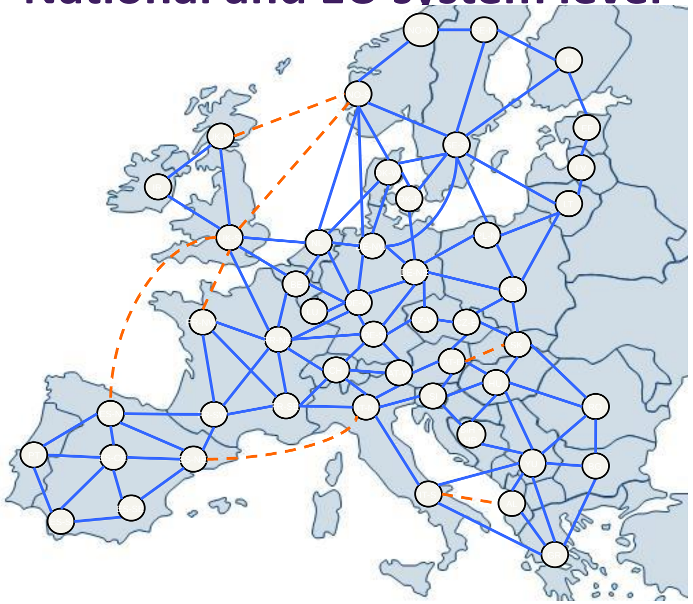
wholeSEM

Local district level

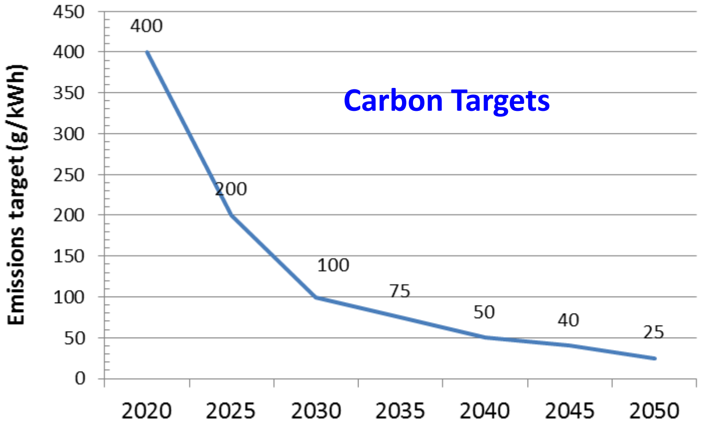


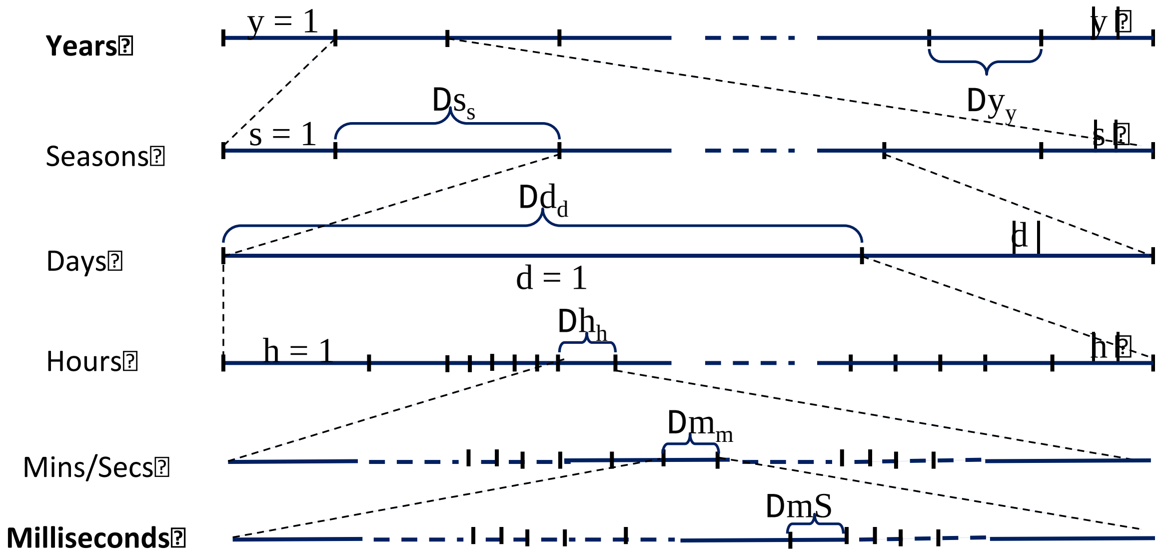


National and EU system level



Space

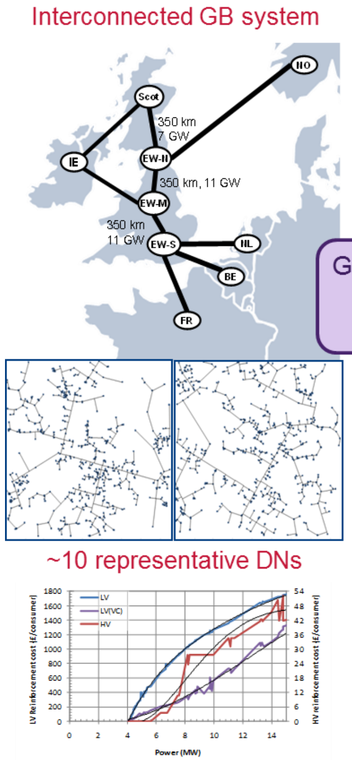


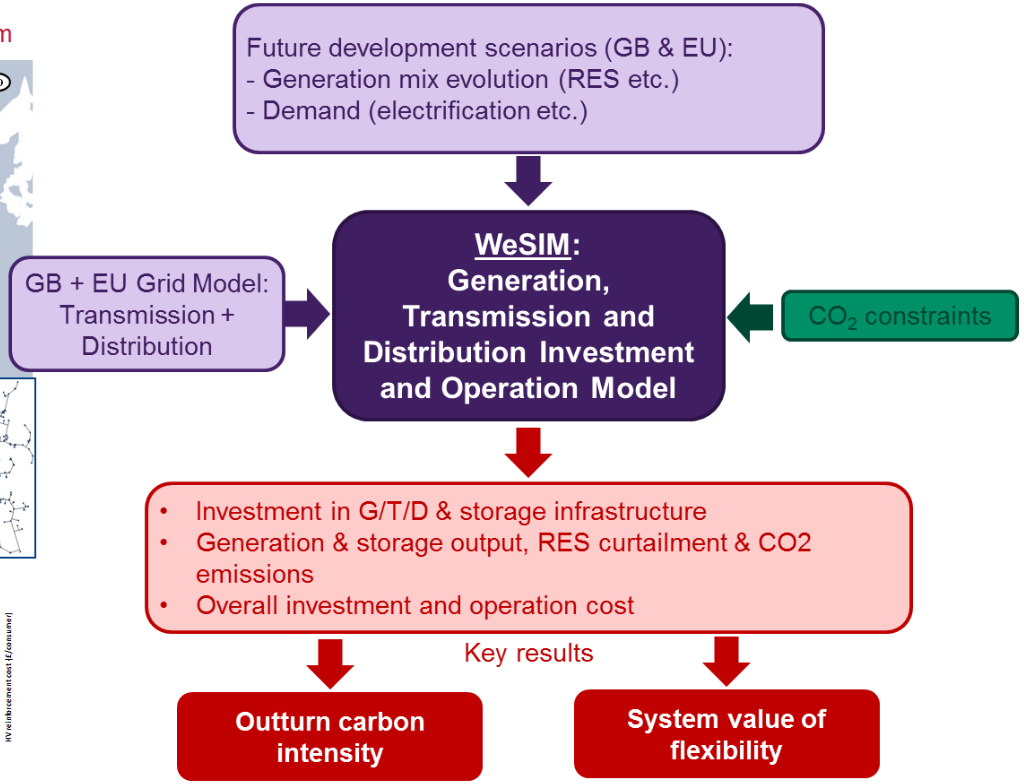


Time

Whole-electricity System Model (WeSIM)

- Makes optimal investment and operational decisions that minimise total system cost:
  - Generation CAPEX
  - Transmission CAPEX
  - Distribution CAPEX (Representative Networks)
  - OPEX
- High temporal and spatial resolution
- Finds least-cost solution whilst ensuring that system-level CO_2 constraint is met
- Advanced treatment of system inertia and frequency regulation requirements
- Highly suitable for evaluating flexible options (storage, DSR, interconnection, flex. generation…)
- Used in a number of studies to evaluate the role and value of flexibility in low-carbon UK power system (CCC, BEIS, Carbon Trust, NIC etc.)





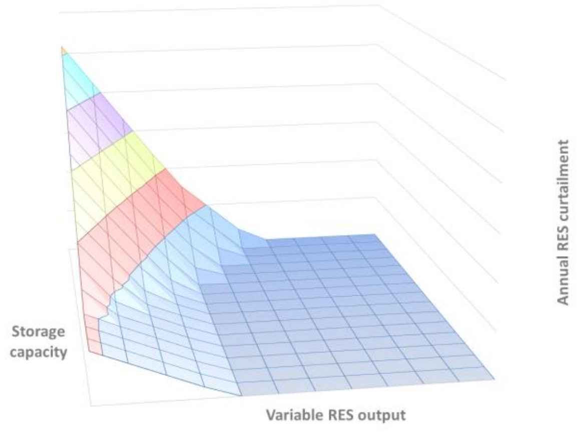
Model integration approach

- Two key models:
  - **UKTM** – low-resolution, all-energy system, technology-rich model
  - **WeSIM** – high temporal and spatial resolution model of electricity system
- Key parameter adopted to quantify the ability of electricity system to integrate VRE: output **curtailment**
  - Function of flexibility
  - Requires high-res modelling (WeSIM)
- **Proposed linking** of UKTM and WeSIM: use multiple WeSIM runs to represent VRE curtailment as function of two variables:
  - VRE penetration (or installed capacity)
  - Level of flexibility in the system
- Represent curtailment levels as constraints on annual output of VRE in UKTM

WeSIM

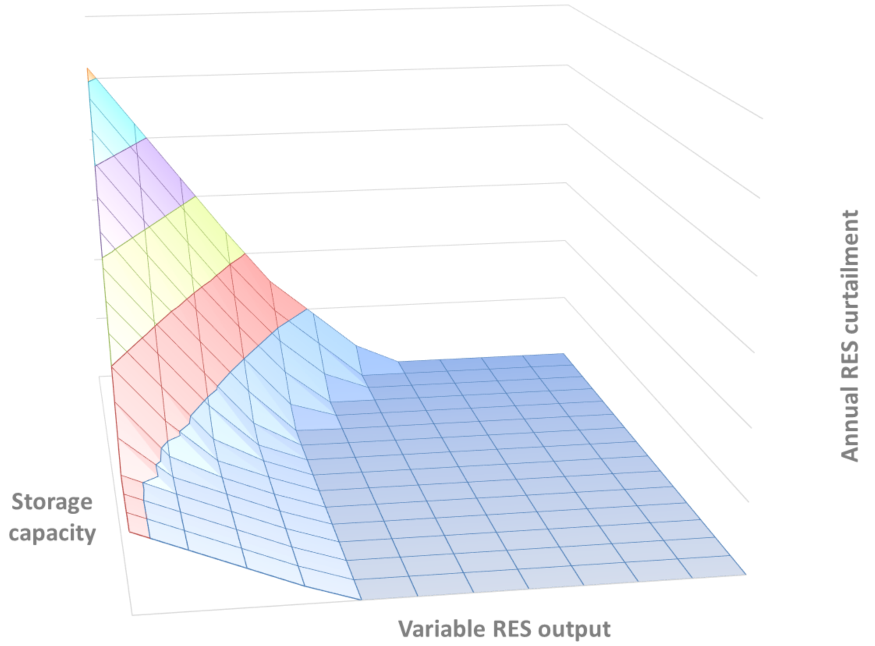
Curtailment of VRE
= f(installed VRE, Flex)

UKTM



Implementation

1. Run a number of WeSIM simulations to quantify VRE curtailment (*z*) as function of:
   - Varying VRE (wind + PV) penetration (*x*)
   - Varying installed storage capacity (*y*, proxy for system flexibility)
2. Use these data points (*x*,*y*,*z*) to construct planes through triplets of adjacent points: $z_i = A_i x + B_i y + C_i$
   - Results in a piecewise linear 3D curtailment surface
3. Constrain annually available output of VRE in WeSIM: $E_{VRE} \leq E_{VRE}^{avail} - z_i \; \forall i$

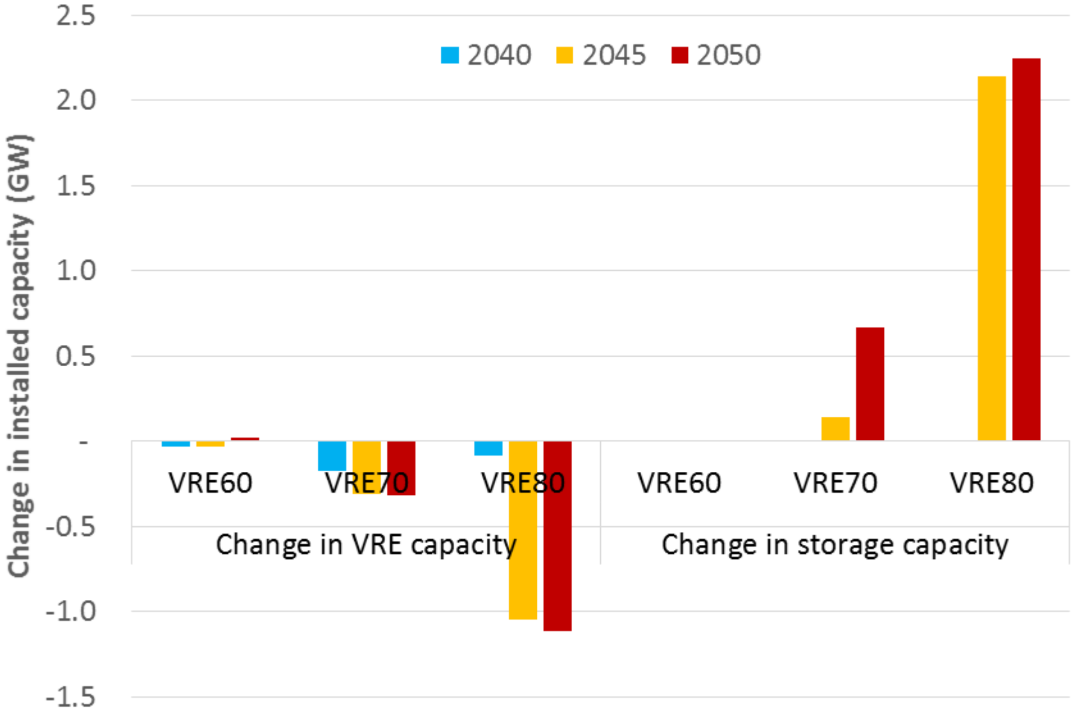


- Curtailment of VRE may trigger investing in energy storage to ensure a more efficient VRE integration.
- This will provide a proxy for the System Integration Cost (SIC), enabling a fair comparison to other low-carbon technologies (e.g. nuclear).

Preliminary results

- We analysed three high-level scenarios in terms of VRE share in 2050 electricity supply:
  - VRE penetration = 60% (VRE60)
  - VRE penetration = 70% (VRE70)
  - VRE penetration = 80% (VRE80)
- UKTM was run for these scenarios with and without the modification to account for VRE curtailment
- As expected, the modification of UKTM resulted in ***lower installed VRE capacity*** and ***higher storage capacity***
- Impact of proposed approach more pronounced at high VRE levels

(Note that UKTM can shift demand from/to electricity sector given its multi-vector dimension. This is why the same VRE penetration could be maintained with lower capacity.)



Future refinements

- Additional testing and validation
- Include other influencing variables:
  - Demand
  - Nuclear capacity
  - Other forms of flexibility
- Increase number of data points used to construct 3D curtailment surface
- Separate curtailment for wind and PV
- Refine cost assumptions on VRE, nuclear and energy storage to identify tipping points
  - When does VRE become more competitive than nuclear?

vs.

EPSRC
Pioneering research and skills