Assessment of the Wind Integration Potential of Residential Thermal Storage

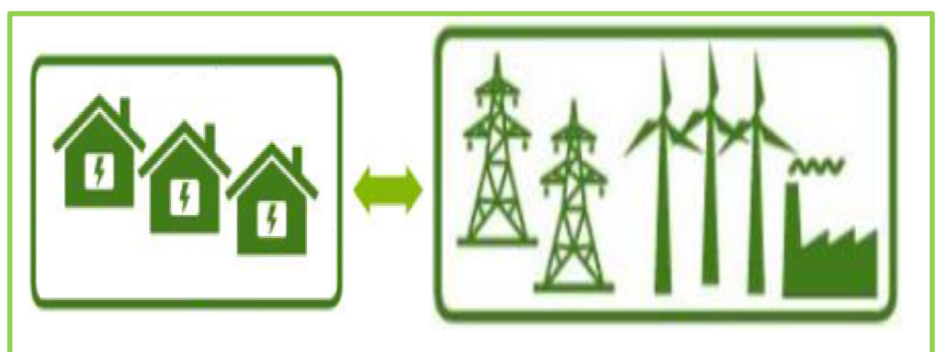
Muhammad Bashar Anwar[1] (muhammad.anwar@ucdconnect.ie) , **Daniel J. Burke[2], Prof. Mark O'Malley[1]**

[1]Electricity Research Centre, University College Dublin / School of Electrical and Electronic Engineering

[2]Electrical Engineer, Warwick, UK

Introduction

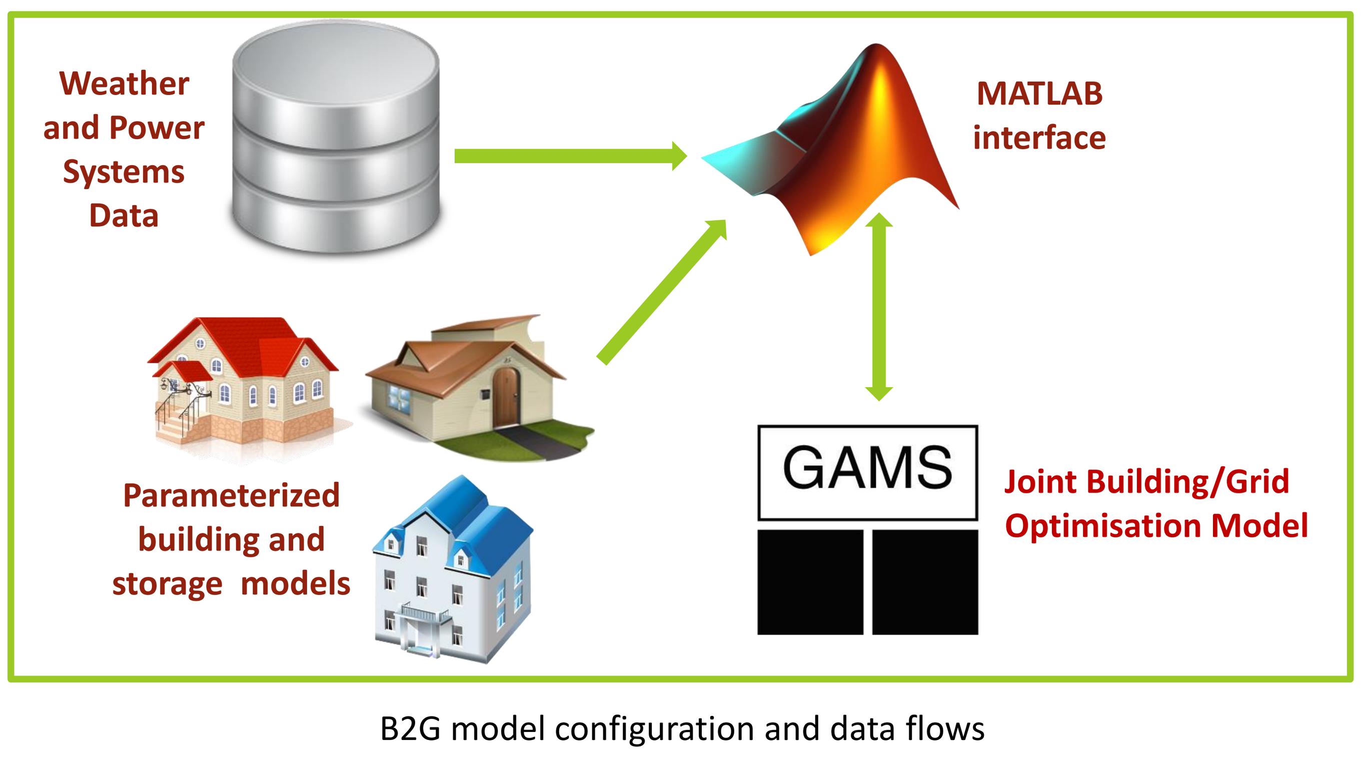
- ❑ Large-scale grid integration of variable renewable generation can result in various techno-economic concerns for the operation of power systems.
- ❑ Residential thermal storage can allow decoupling of electrical power consumption of heating loads from the time of thermal energy end-use
- ❑ Thermal storage capability of residential heating loads can enhance power system flexibility and can potentially facilitate grid integration of renewable generation.



Building-to-Grid Model

Proposed Methodology

- ❑ Building-to-Grid (B2G) model – integrates thermal dynamics and end-use constraints of residential heating loads within a detailed Unit Commitment model.
- ❑ Annual system-wide analysis of the wind integration potential of residential thermal storage for the All Island Power System (AIPS) of Ireland.
- ❑ Consideration of several factors including storage capability of the active and passive thermal storage, wind penetration levels, and participation of heating loads in various categories of system reserve.



B2G model configuration and data flows

Thermal Demand Modelling

- ❑ Domestic space heating demand is modelled using lumped parameter (RC-equivalent) state space models [1].
- ❑ Domestic hot water (DHW) demand is developed by combining the average daily DHW consumptions with the probability distributions for the corresponding hot water draw activities determined by the Time-of-Use Survey (TUS) data [2].

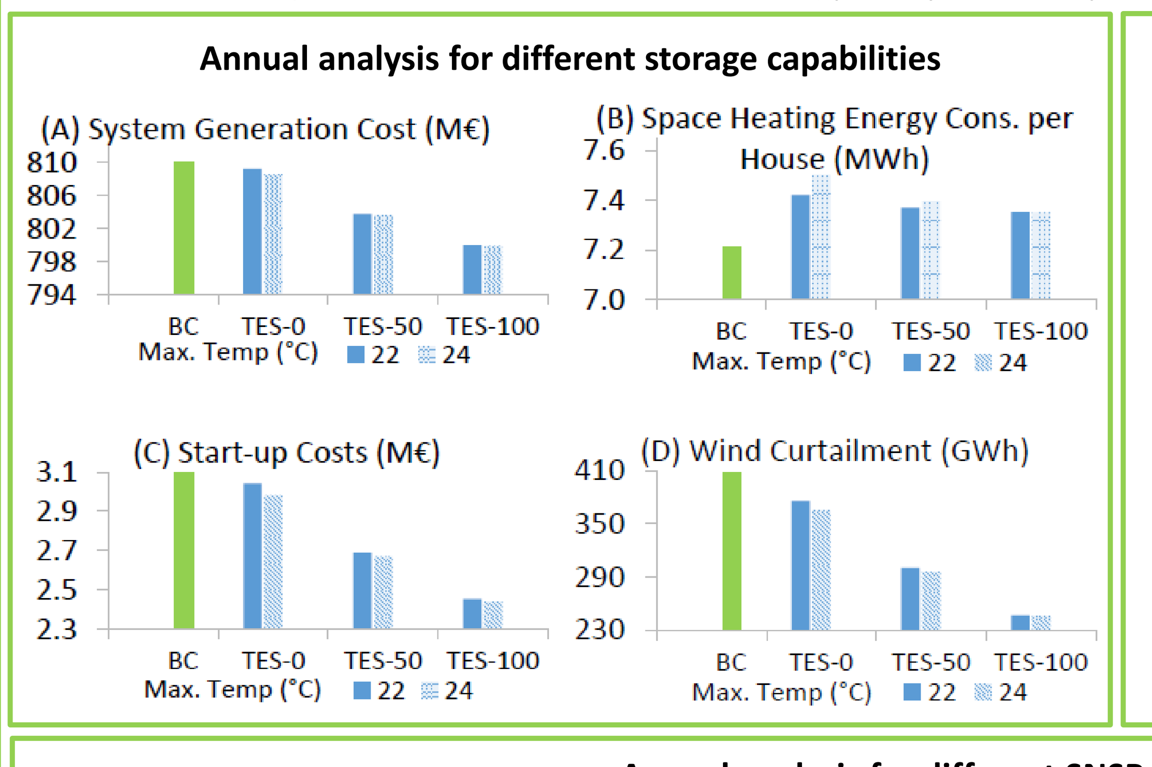
Building-to-Grid (B2G) Model

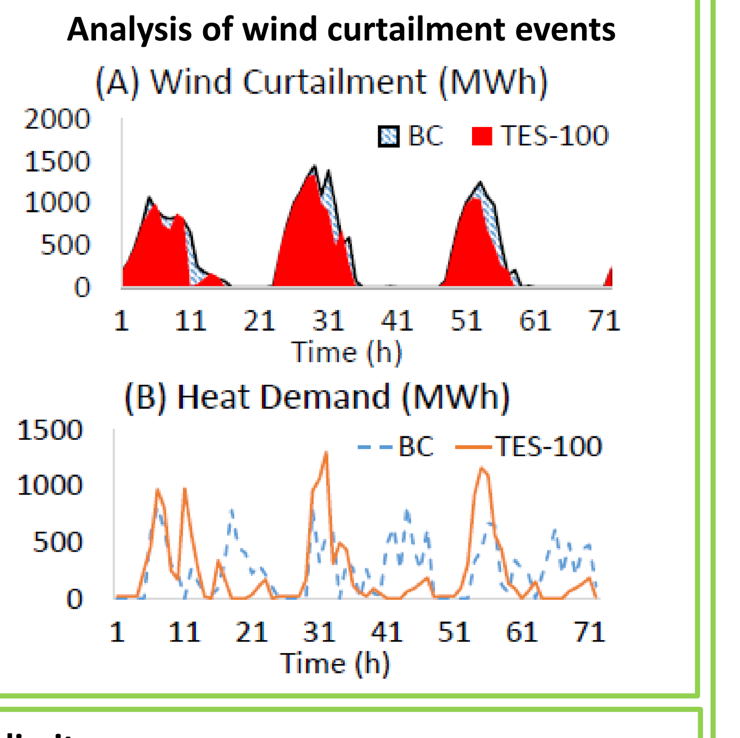
- ➢ The objective function of the B2G model minimises the system operating cost which consists of generation fuel costs, start-up costs and carbon prices.
- ➢ The cost minimisation is subject to the following constraints:
  - ➢ System operation constraints
  - ➢ Generators' technical constraints
  - ➢ Thermal demand operation constraints (minimum and maximum limits for the indoor and DHW tank temperature, heating technology constraints).
  - ➢ Heating technologies: Direct Resistive Heaters (DRH) and Thermal Energy Storage (TES) devices.
  - ➢ Thermal comfort based reserve provision constraints – ensure that participation of heating loads in reserve provision doesn't violate consumer thermal comfort requirements.

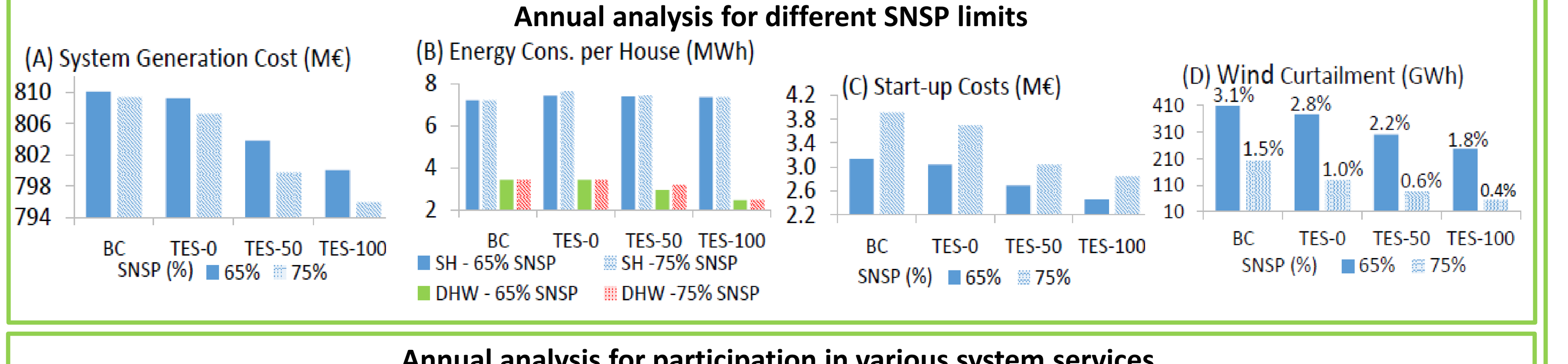
Results

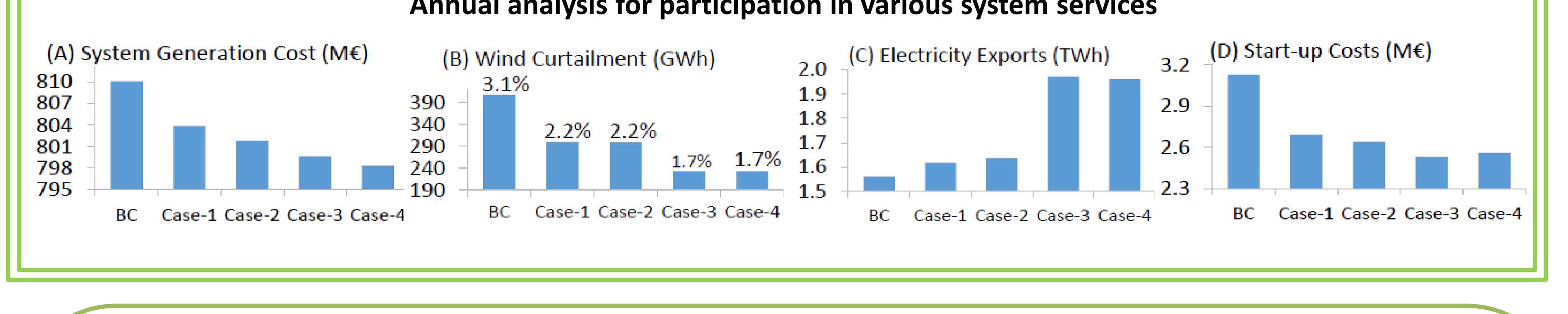
Heat Demand Scenarios:
BC: Base Case (Inflexible heating load);
TES-0: 100% DRH, 0% TES;
TES-50: 50% DRH, 50% TES;
TES-100: 0% DRH, 100% TES.

System Service Participation Cases:
Case-1: Energy Arbitrage (EA) only;
Case-2: EA, primary under-frequency and tertiary reserves;
Case-3: EA, primary over-frequency and tertiary reserves;
Case-4: EA, primary under-frequency, primary over-frequency and tertiary reserves;









Conclusions

- ❑ Active thermal storage can allow greater utilisation of wind, and reduction in conventional plant start-up costs as compared to passive storage.
- ❑ The wind curtailment reduction potential of thermal storage is constrained by the magnitude of heating load during large wind curtailment events.
- ❑ Provision of over-frequency reserves results in a greater impact on wind curtailment reduction as compared to provision of under-frequency reserves

References:

[1] M. B. Anwar, C. A. Cabrera, O. Neu, M. O'Malley, and D. J. Burke, "An integrated building-to-grid model for evaluation of energy arbitrage value of thermal storage," in Students on Applied Engineering (ISCAE), International Conference for. IEEE, 2016, pp. 64–69.

[2] O. Neu, S. Oxizidis, D. Flynn, and D. Finn, "Utilising time of use surveys to predict domestic hot water consumption and heat demand profiles of residential building stocks," British Journal of Environment & Climate Change, vol. 6(2), pp. 77–89, 2016.

Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646116