ID: 172

Demand-side response for grid-independent islands based on flexible energy management using heat pumps

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ABSTRACT

Large-scale deployment of local renewable energy sources (RES), coupled with demand-side response (DSR), is viewed as a critical strategy for improved energy security on geographic islands.[1]

REACT is a 4-year European project to address the challenges associated with DSR from the perspective of geographic islands with limited electrical grid access.[2]

This simulation case study focuses on the island of Inishmore, western Ireland, under a future increased-renewables scenario in which the heating demand for 65% of the island's 300 dwellings is provided by air-to-water heat pumps.

SIMULATION RESULTS

Baseline case

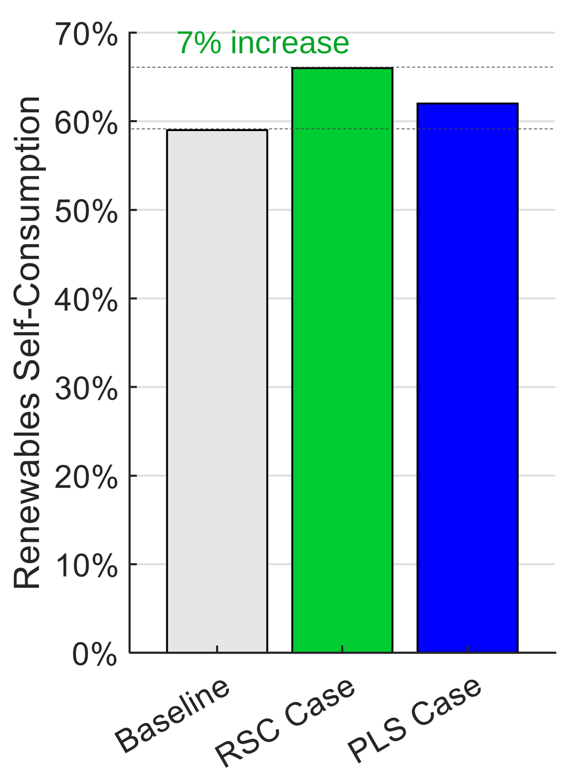
The yellow and pink areas represent the electricity consumed by the heat pumps to provide space heating (SH) and domestic hot water (DHW) to all dwellings. A large peak occurs at 08:00 due to the demand for hot water. Without demand-side response, the electricity consumption generally shows a poor match with the available renewable energy generation.

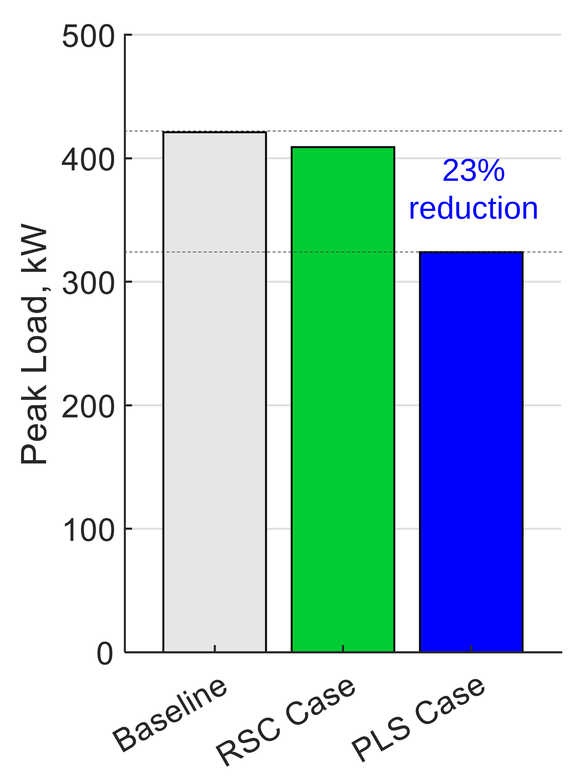
Renewables self-consumption (RSC) case

DSR control is activated during the period of surplus RES generation between 11:00 and 15:30. The solid red line shows the number of additional heat pumps activated in order to raise the electricity demand and maximise self-consumption. By operating the heat pumps flexibly to charge the DHW storage to an increased temperature, the total RES self-consumption is increased from 59% to 66% over the annual period.

Peak load shifting (PLS) case

The peak load shifting case seeks to flatten the energy consumption profile in line with the previous 24-hour average. By running the heat pumps to charge the DHW tanks during hours of lower electricity demand, the annual-average daily load factor is increased to 65% compared to 48% in the baseline case; while the daily peak load is reduced by 23% from 421 to 324 kW.



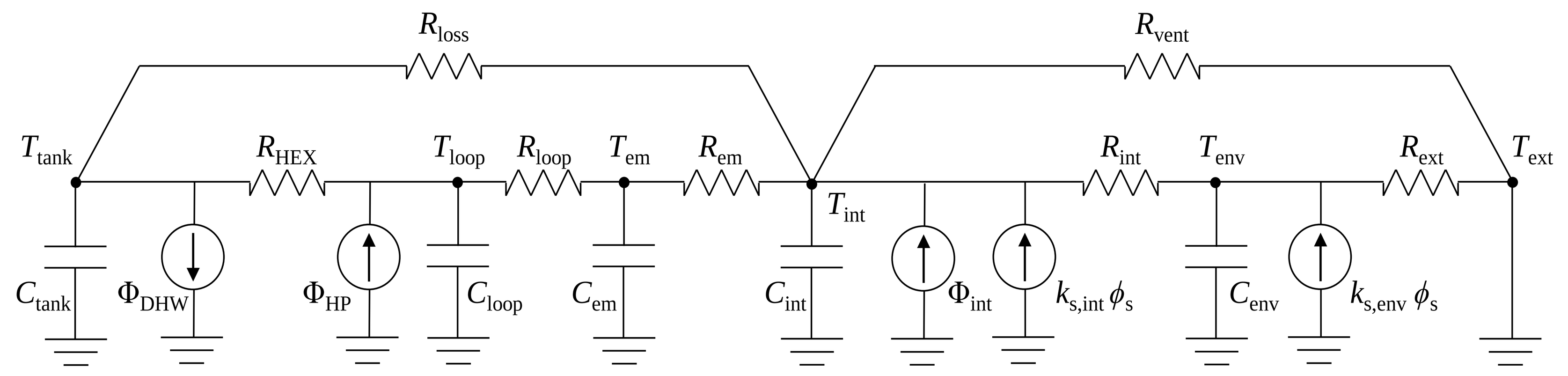


MODELLING APPROACH

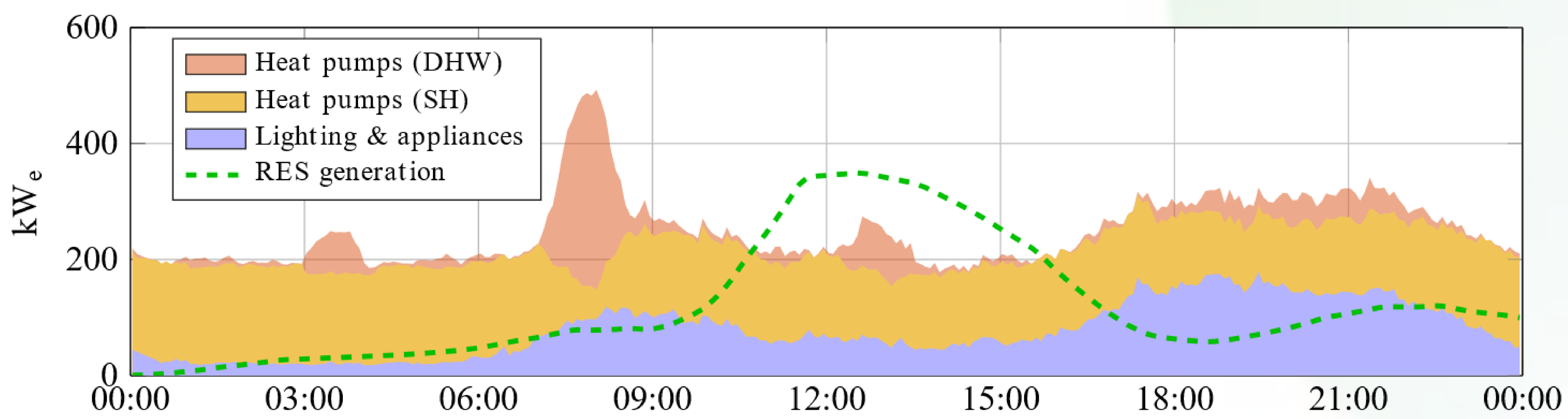
A community energy-system model was implemented in MATLAB, using a reduced-order modelling approach to represent the heat dynamics of the individual buildings.

The model of the island energy system consists of the following components: (i) simplified thermal models of each dwelling, including heat pumps with domestic hot water (DHW) storage; (ii) a heat pump controller sub-model; (iii) a renewable energy system (RES) sub-model; and (iv) the demand-response control platform sub-model.

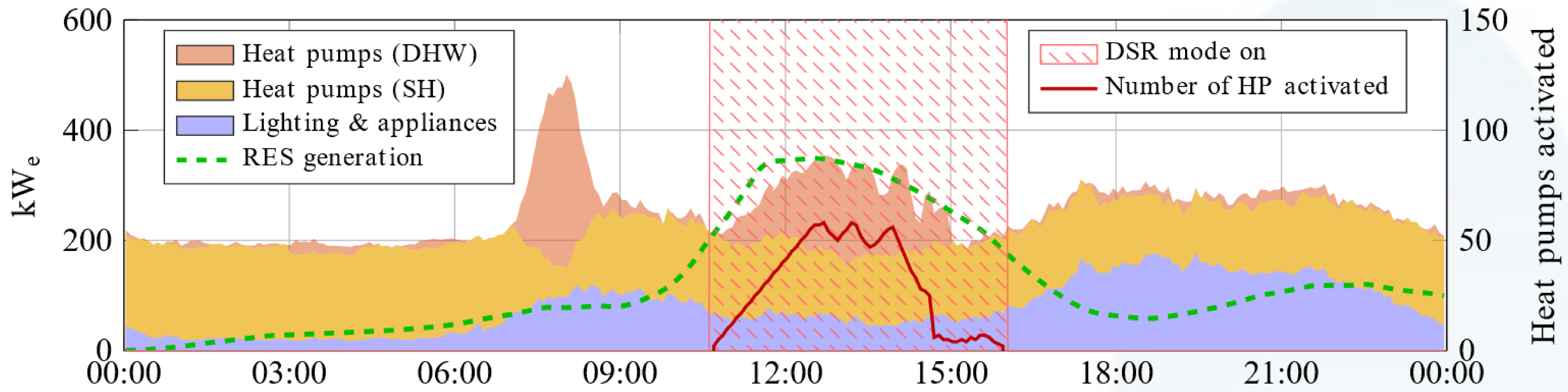
Based on a future increased-renewables scenario, the RES sub-model was optimally sized to give a nominal installed capacity of 350 kW_p solar-PV and 450 kW wind.



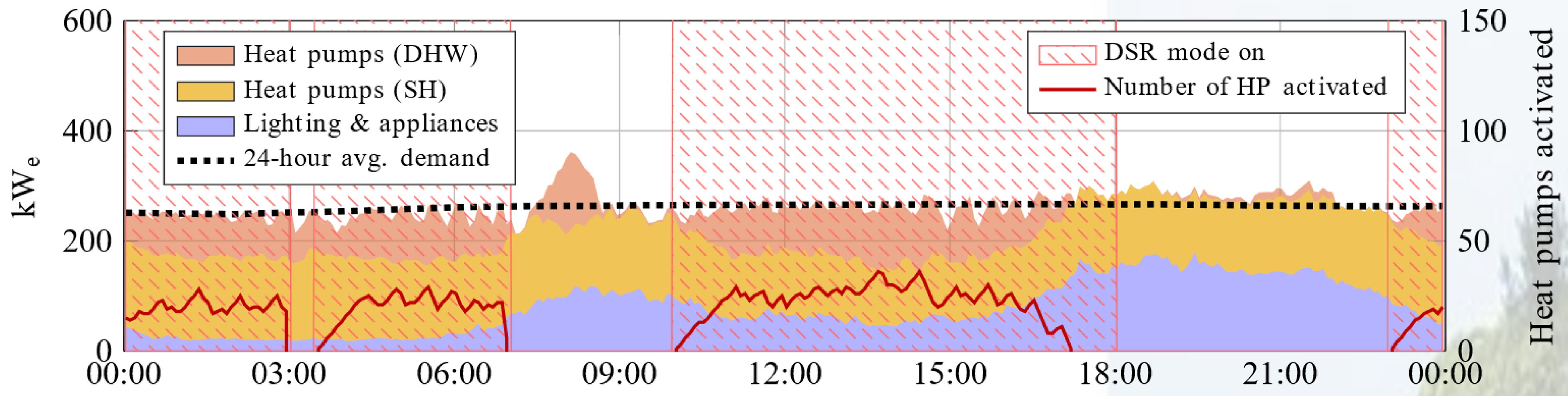
Resistance-capacitance (R-C) thermal model representing a single dwelling.



Baseline case, showing a single-day energy profile from the annual simulation.



Renewables self-consumption case



Peak-load shifting case

CONCLUSIONS

- This work demonstrated that a form of rule-based control implemented at the DSR platform level can effectively manipulate the energy use of a cluster of heat pumps to impact the electricity load profile at the community level.
- The potential for energy savings through DSR is affected by the daily and seasonal variations in the renewables generation profiles and heating demands of the buildings.
- Future work in this project will consider RES shared self-consumption using combinations of thermal and electrical energy storage.

REFERENCES

1. European Commission, Clean energy for EU islands, 2017, https://ec.europa.eu/energy/topics/renewable-energy/initiatives-and-events/clean-energy-eu-islands_en
2. H2020: REACT. Renewable Energy for Self-sustainable Island Communities, 2019, https://react2020.eu/

This project has received funding from the European Union's H2020 programme under Grant Agreement No. 824395