Project SWELL (academic component a.k.a. CEGADS)

MAKING LEGACY DOMESTIC THERMAL STORAGE HEATING FIT FOR THE SMART GRID

COMMUNITY ENERGY, DATA AND MODELS

Modelling using: Agent-based Modelling of Electricity Networks

Innovate UK

EPSRC Pioneering research and skills

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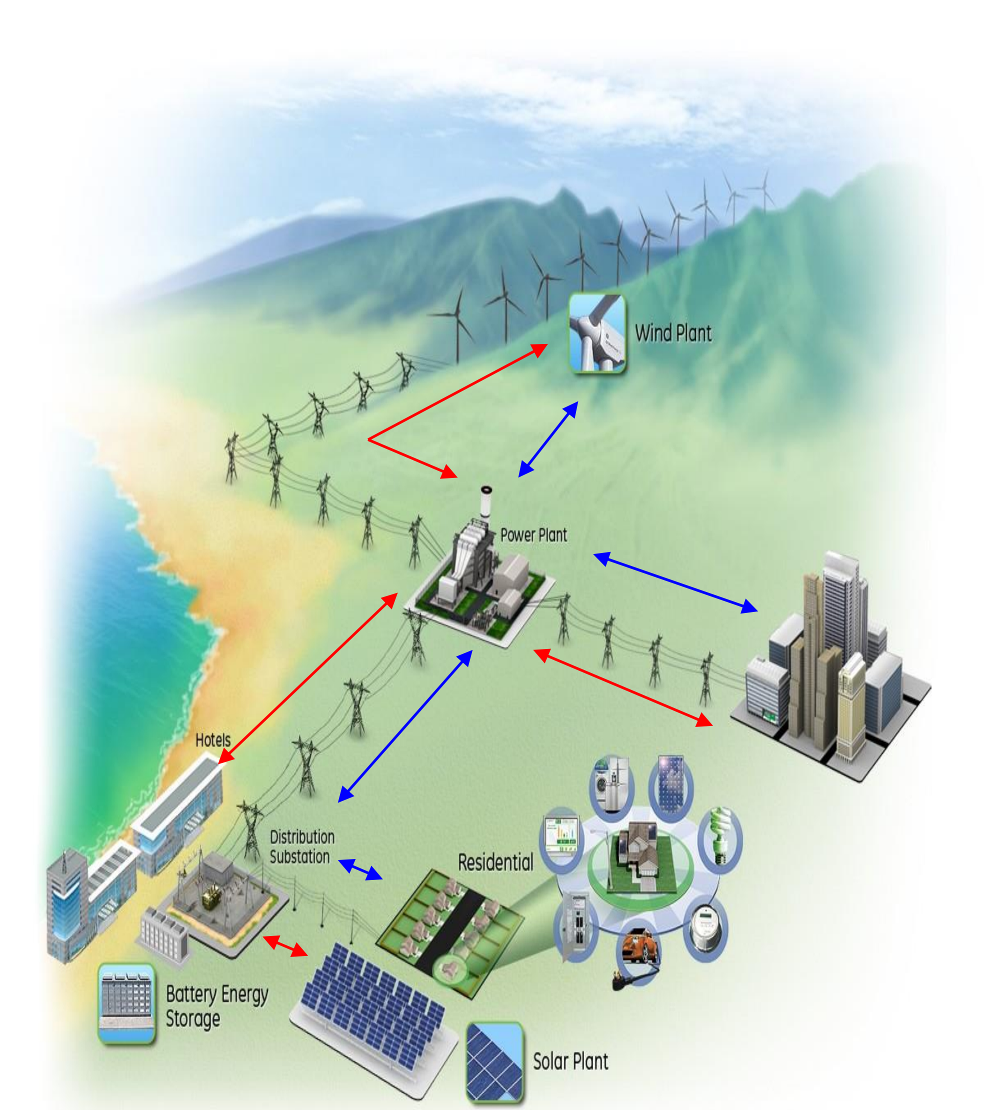


Context

- 2050 Carbon reduction commitments
- ~30% of energy consumption is from domestic users [1]
- Pathways to 2050 carbon levels rely on smarter use of energy in the presence of electrification and renewable generation: Smart Grids
- Change in domestic sector relies on household adoption of new behaviour and technology
- Benefits of community networks and local balancing recognised in UK's Community Energy Strategy [2] and academic work both social (e.g. [3]) and technical (e.g. [4])

Community energy – how?

- Demand shaping (a.k.a. Demand Side Management, Demand Side Response)
- Can be automated and manual
- To move demand temporally need
  - Willingness to defer job (manual)
  - Storage
    - Building fabric (via heating)
    - Water (via heating)
    - Batteries
- This presentation concentrates on heating, with some wider consideration of community energy
  - Based on [5]

CEGADs community

Sources: Wikimedia (aerial shot of Shrivenham)

http://www.oxfordshirevillages.co.uk/

Technical characteristics

- ~50 kWp nominal PV installed

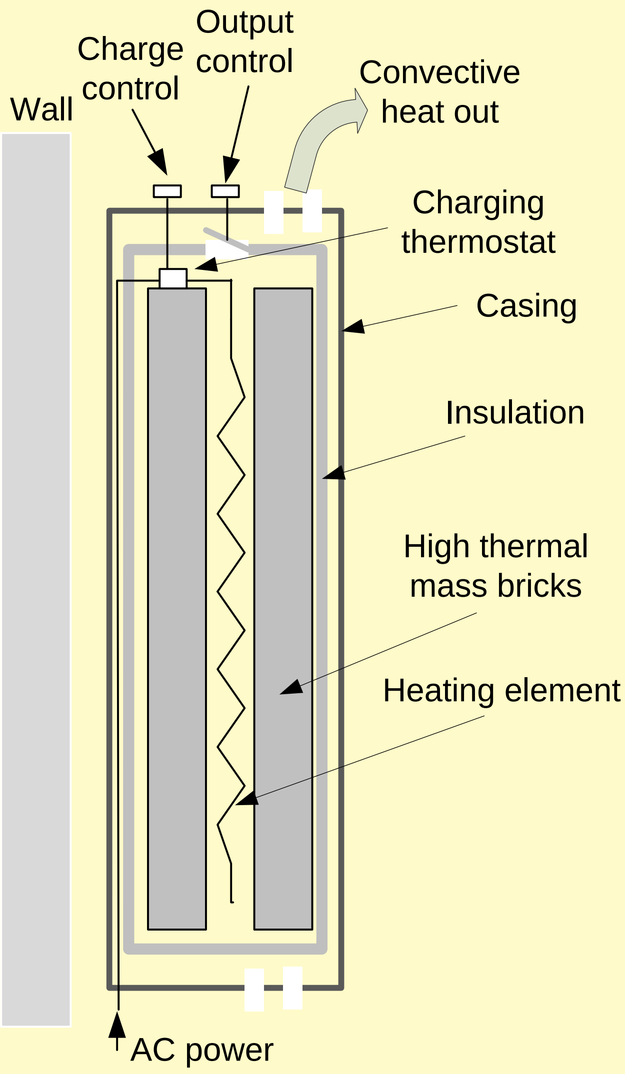
- 6 participants with electrical heating
- ~10-20% of overall demand

Demographic characteristics

- Based on survey of 33 participants
- Of respondents giving age all 35+, 86% 50+, 55% 60+
- 3 living alone, all others with partner, 42% with children
- 85% occupied during day
- Lifestyle factors affecting energy usage recorded

The scheme

What is legacy electrical heating?



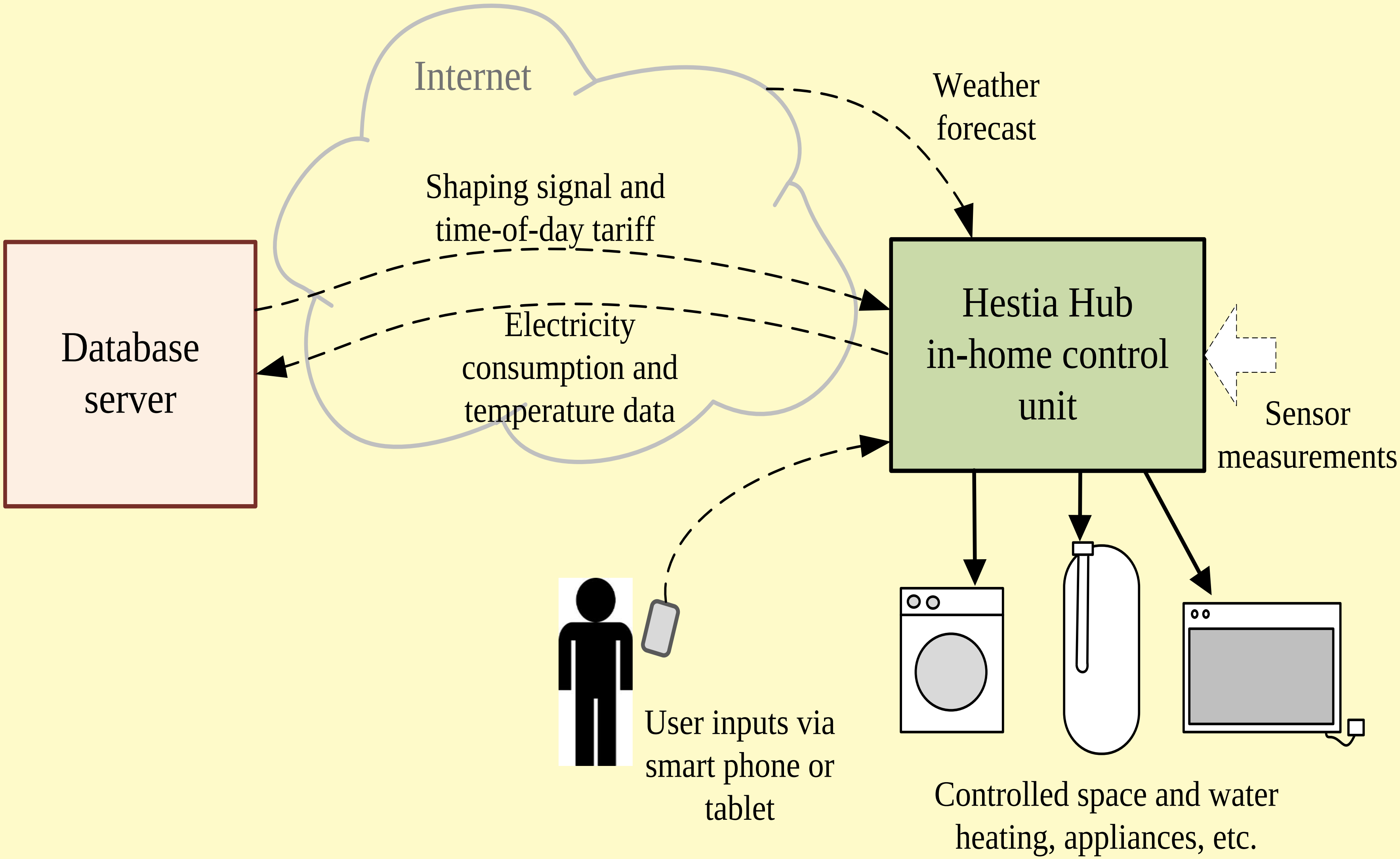
Objectives

- Overall project

  Demonstrate the use of information and a business model to enable use of local renewable generation within the community.

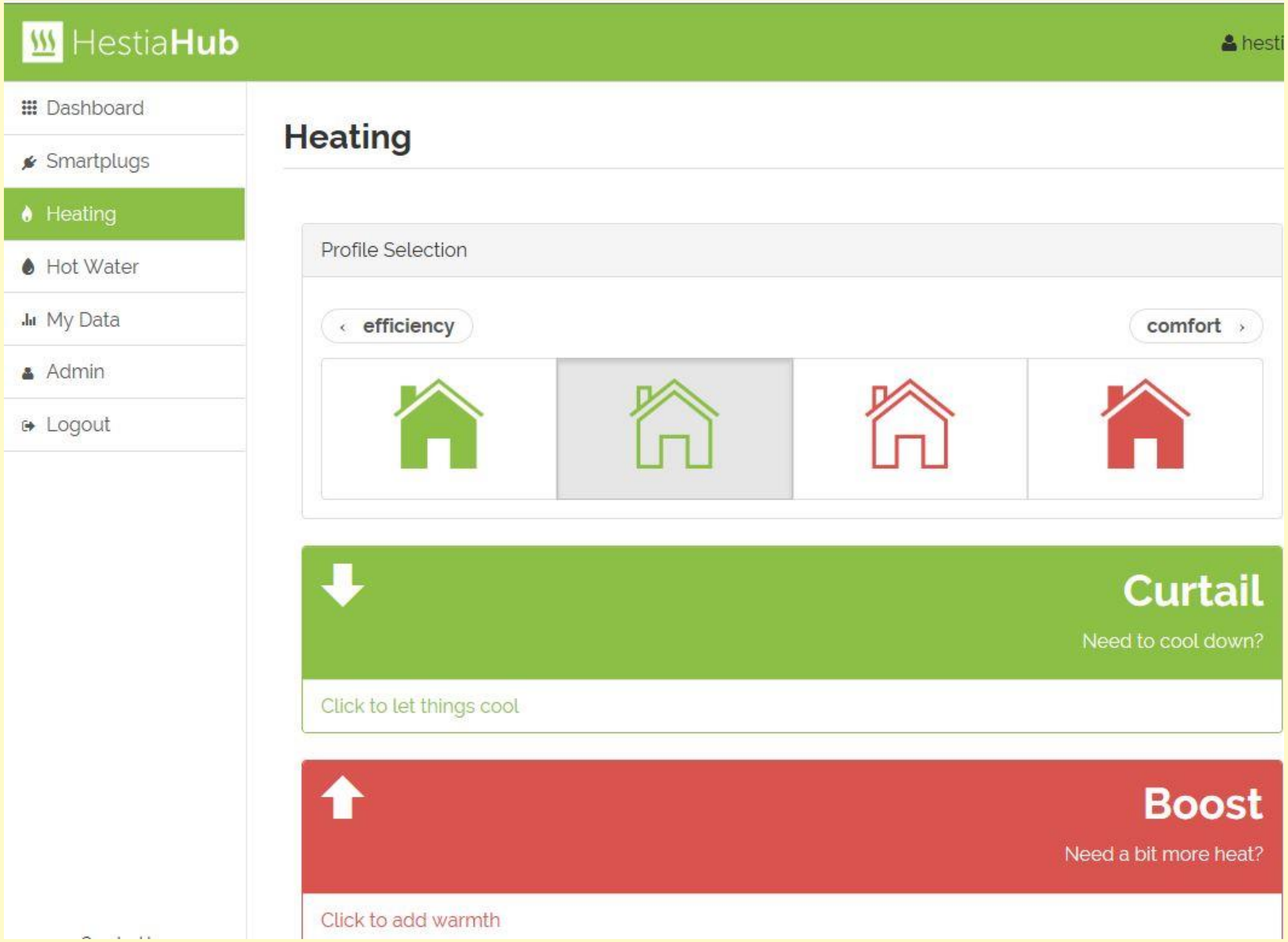
- Automated heating control
  1. Provide more convenient and efficient control for the users while varying the times at which charging is performed,
  2. Flatten the profile of demand and make use of locally-generated renewable electricity
  3. minimise demand during the 17:00-21:00 peak tariff period;
  4. spread demand within the 7 hour overnight period

Control scheme - system



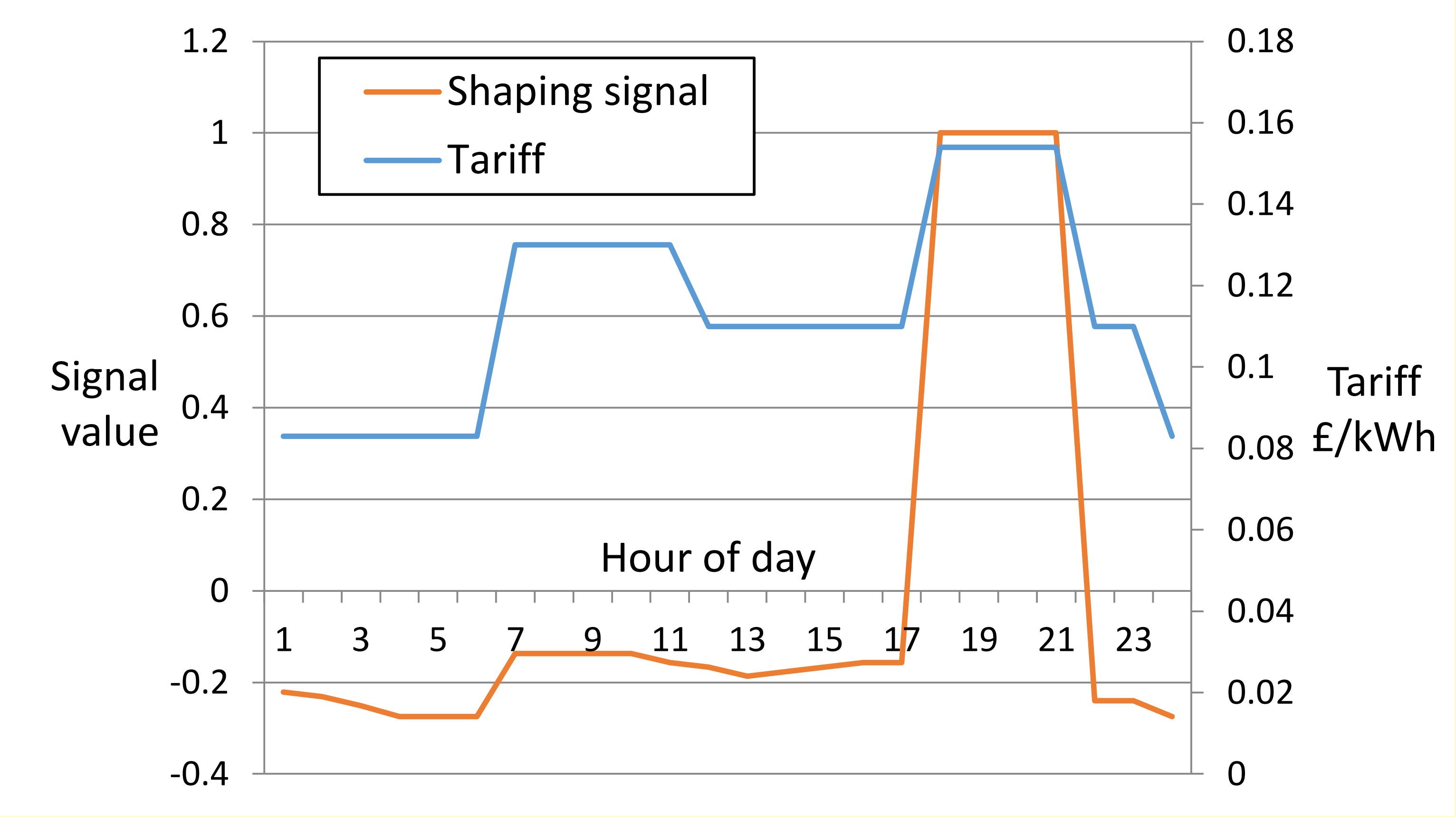
Control scheme - interface

- Make interface easy to understand



Control scheme – under the hood

- Send signal per half hour
  - High – repel demand, Low - attract
- Biased random response to signal



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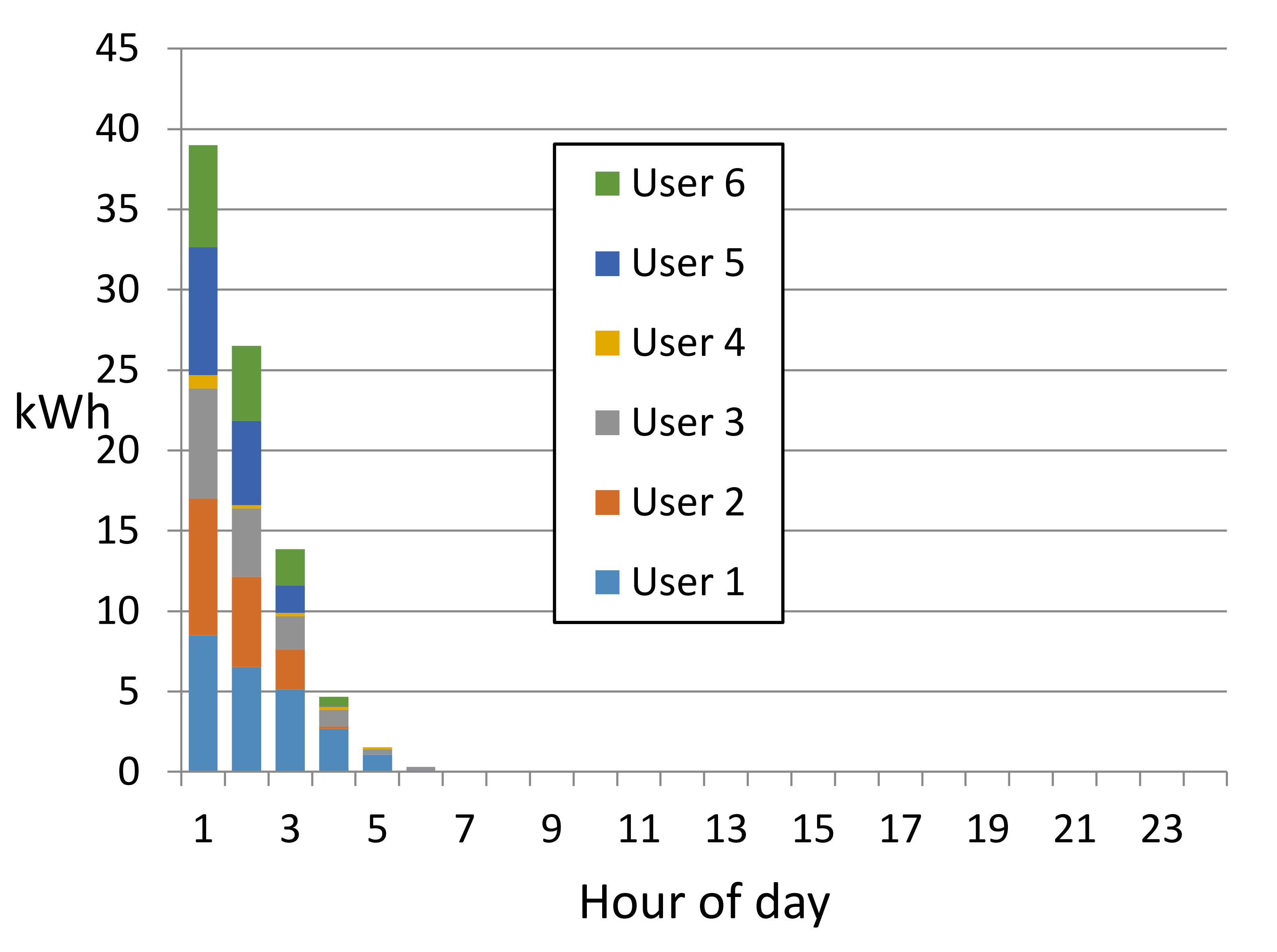
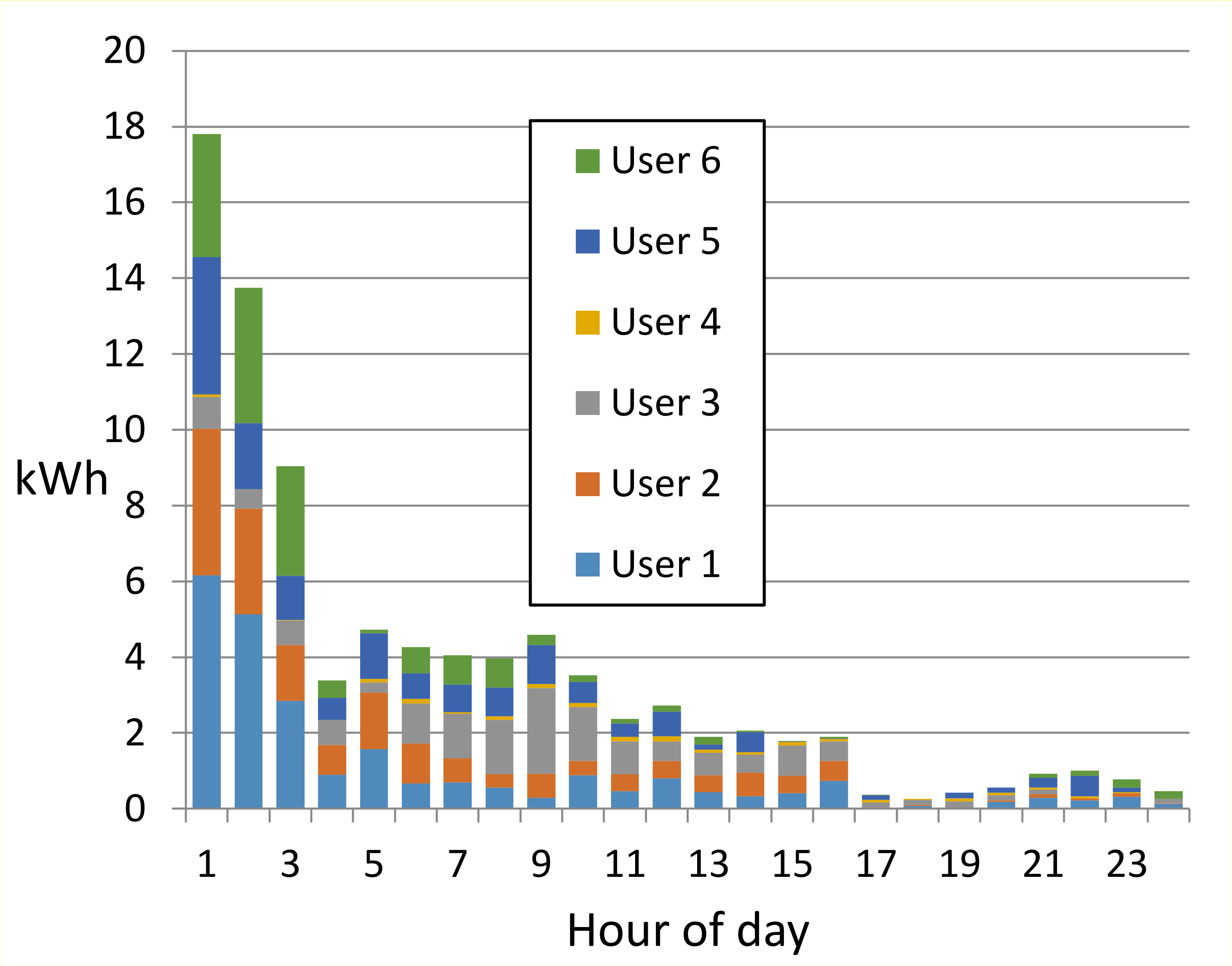
Forecasting

- Naïve
- Generation forecast from predicted insolation
  - Simple multiplier based on past data
- Demand forecast
  - Today will be much like past days
  - Can tailor based on temperature forecast

Sample result – before…



Sample result - …after



Demand shaping outcome

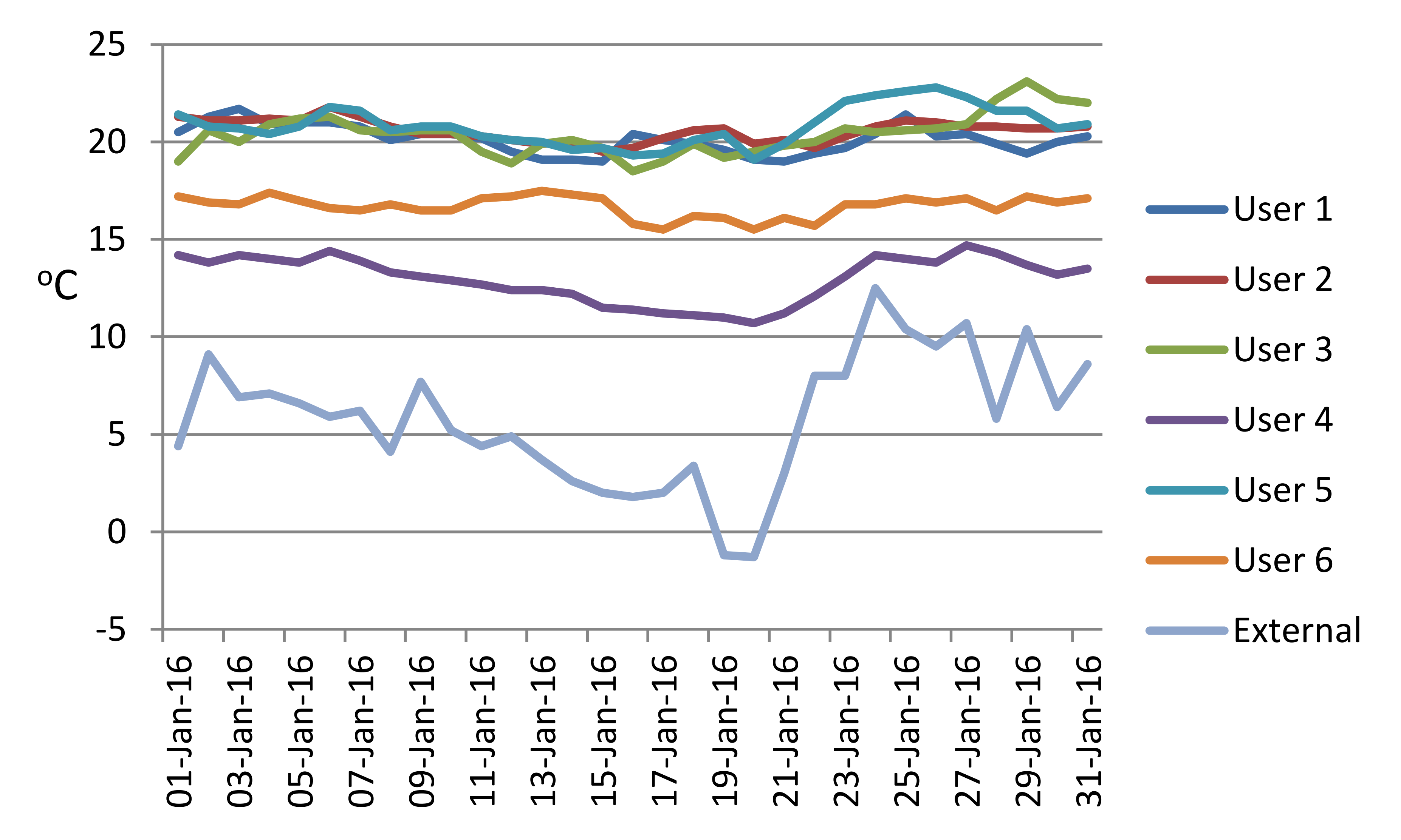
Metric	Jan	Feb	Mar	April	May	June
1.Heating demand during evening high tariff period as % of total heating demand in month	1.8	4.0	4.1	6.3	5.8	6.2
2. Daytime allocation of heating demand excluding high tariff period %	32	38	37	40	48	55
2.Proportion of heating demand when PV generated electricity available %	15	25	33	37	41	46
2. Proportion of heating demand when PV generation available actually satisfied by PV%	5	23	43	66	100	100
3. Reduction in peak heating demand relative to Economy 7 %	54	65	70	83	87	86

Data analysis – heating only

- Weather-adjusted estimates of annual electricity consumption before and after intervention, with expected PV contributions

	User 1	User 2	User 3	User 4	User 5	User 6
Year prior to trial kWh	6583	6205	3731	2383	4345	5362
Year of trial adjusted kWh	6131	3919	4201	2360	4023	4849
Indicated reduction/rise %	-6.9%	-37%	13%	-0.9%	-7.4%	-10%
Local PV generation consumed in year of trial kWh	630	370	488	356	442	390

But are the occupants cold?



Data analysis - money

	User 1	User 2	User 3	User 4	User 5	User 6
Cost at project tariffs	£634	£435	£563	£308	£493	£536
Cost using Economy 7	£627	£583	£606	£372	£559	£548
Indicated cost reduction/rise %	+1%	-25%	-7%	-17%	-12%	-2%

Participant response

‘Oh yes you can put the heating up, yes I've used it yes, I'm using it through the tablet for the living room. The living room I've had to put up … it was very cold Sunday night’ (User 2).

‘as far as I'm concerned, it does what it says on the tin. They promised me no inconvenience and that's what I've got’ (User 4).

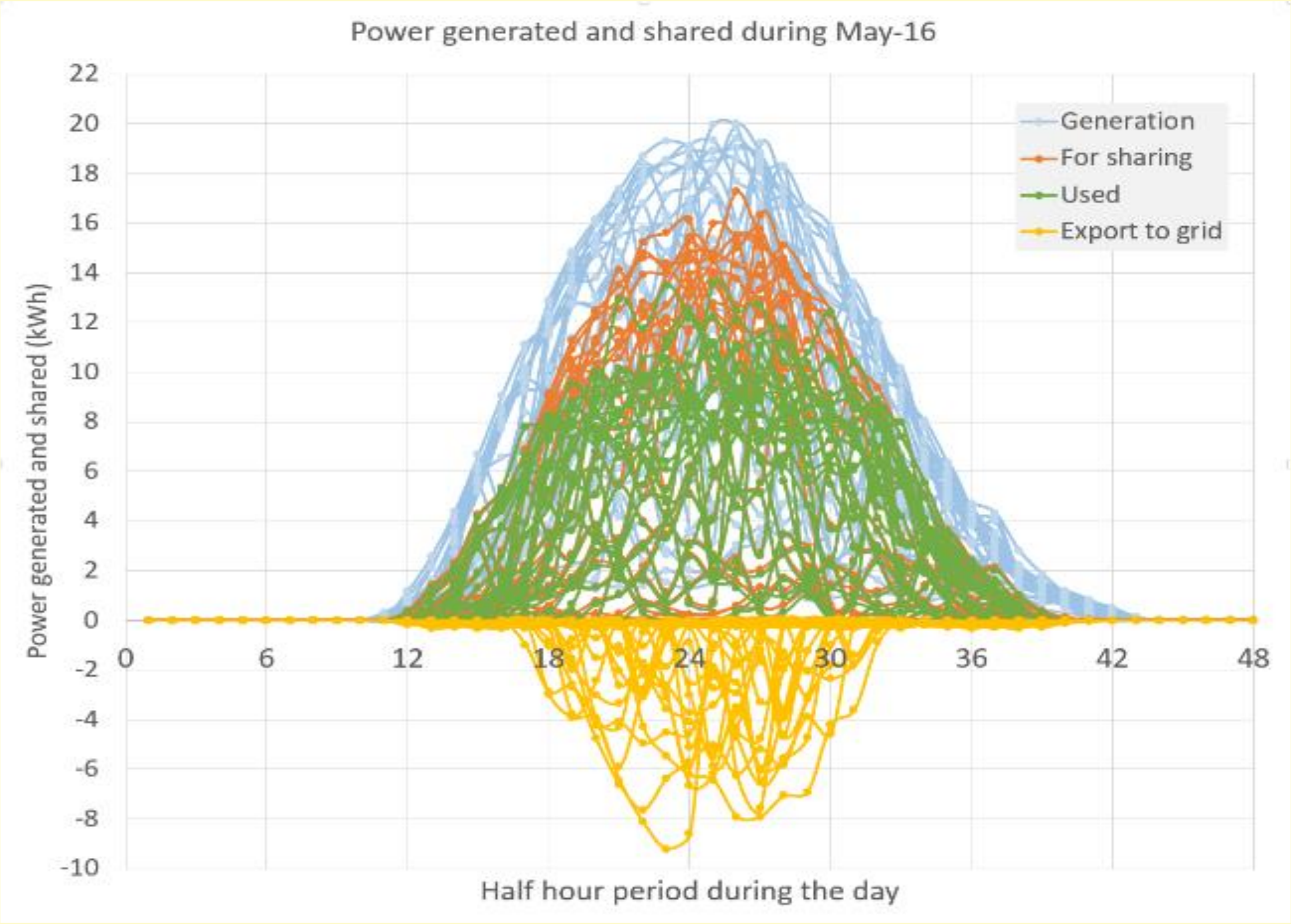
I know it’s a trial system, if and when it could be used, so we could be using local energy, then in due course that could be a good advantage. I don't know if that will ever come about’ (User 6).

‘They provided me with a tablet, and I cannot use it. I am not computer literate’ (User 4).

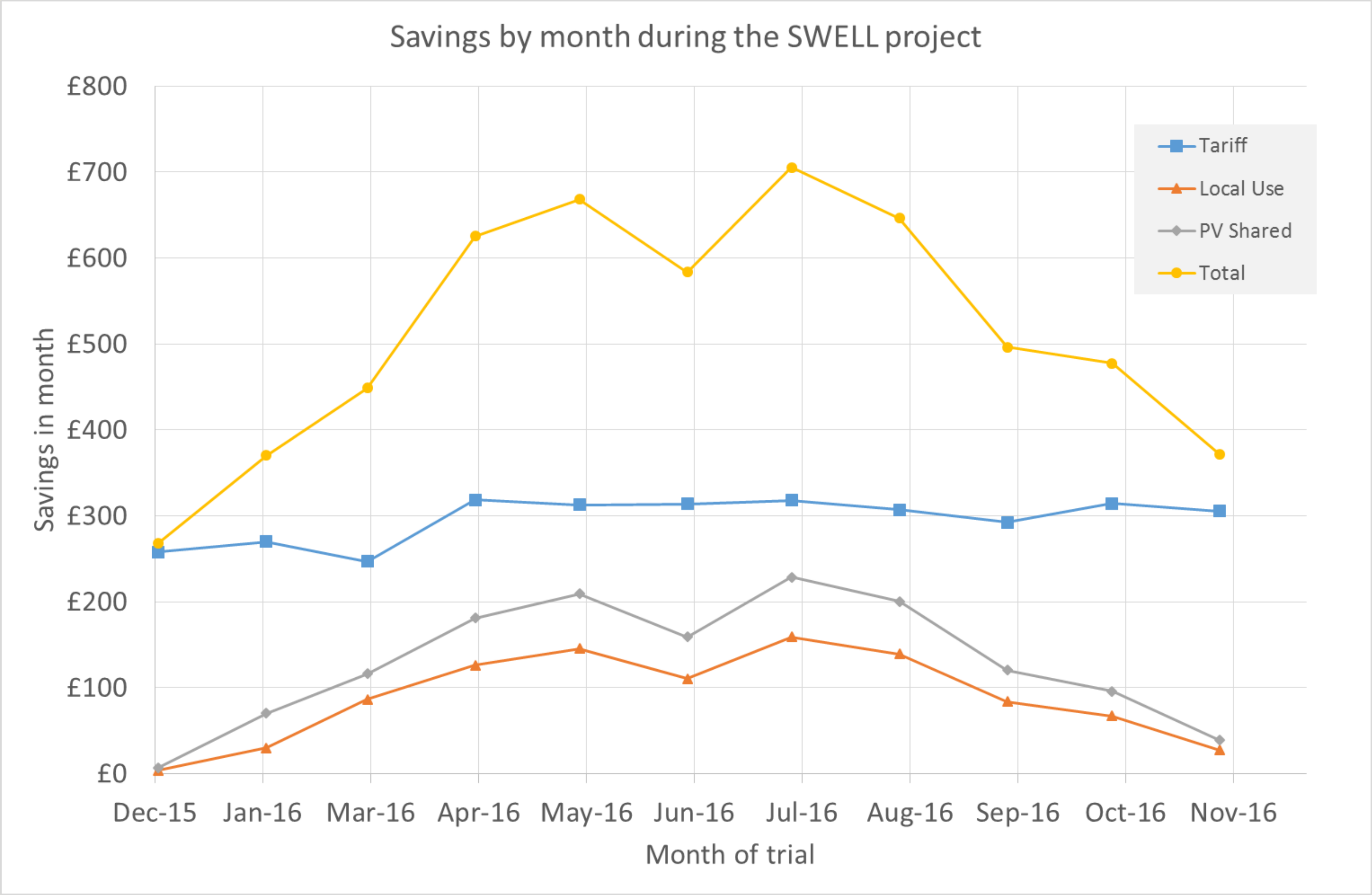
Key findings - heating

- Appliances quite difficult to use efficiently
  - Interaction of charge/discharge control and weather hard to "get"
- Economy 7 gives no flexibility to vary the time of day when charging is performed.
- Scheme trialled broadly successful in achieving its aims for this small group of consumers.
- Participants can save energy and money while maintaining comfort
- Simple interface is necessary
- Effective user engagement programme important
- Manual override must be provided.

Whole scheme data analysis – technical balance



Whole scheme data analysis – financial



Modelling

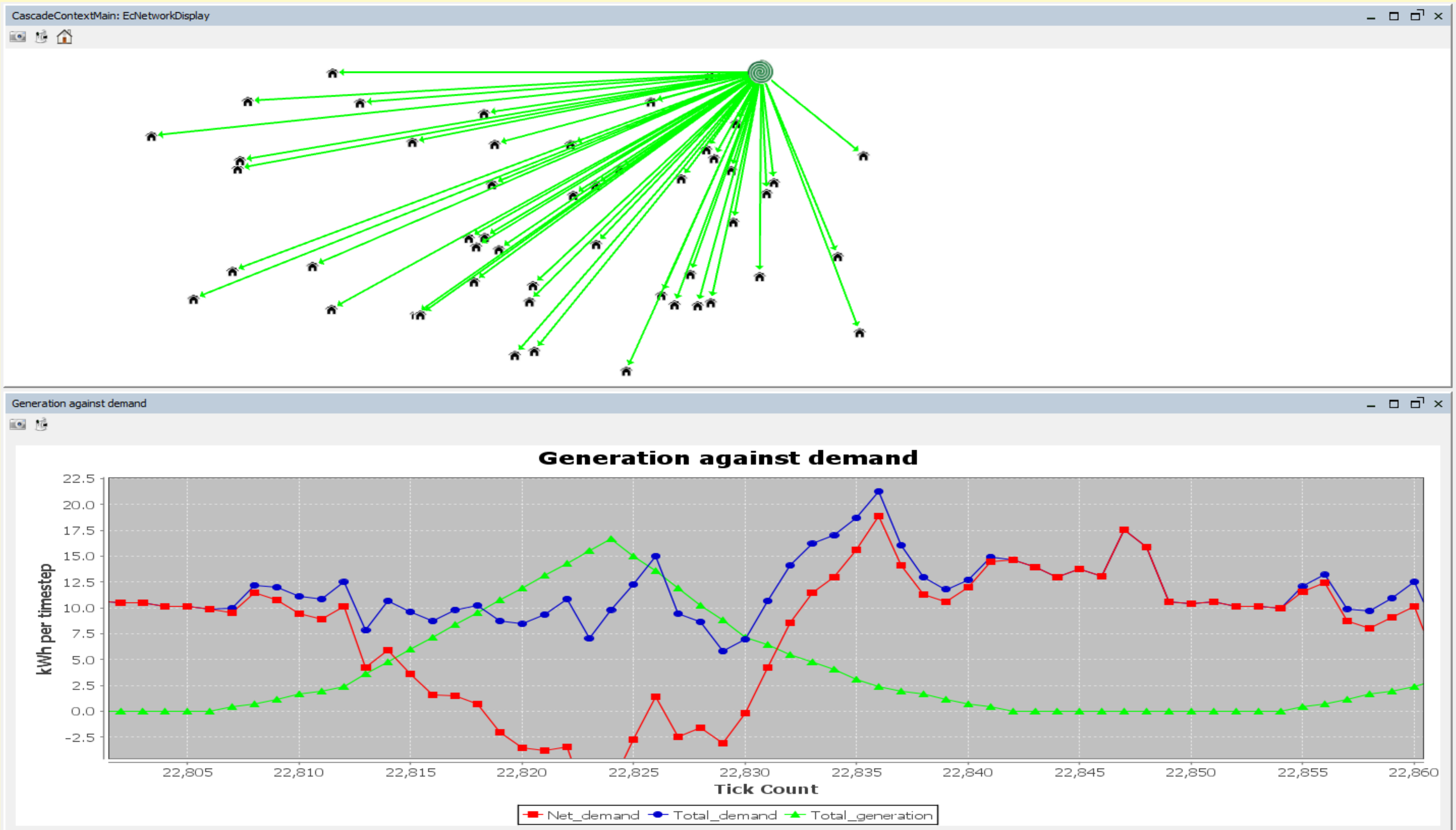
- Question – does this approach scale?
- Agent Based Model
- Rich demand model can accommodate many initial profiles
- Can investigate demographic mixes with differing
  - Occupancy
  - Willingness to shift
  - Appliance ownership
- First replicate the SWELL scenario and cross-check
- Model multiple clubs
- Allow control signal to evolve for each club

Scenarios

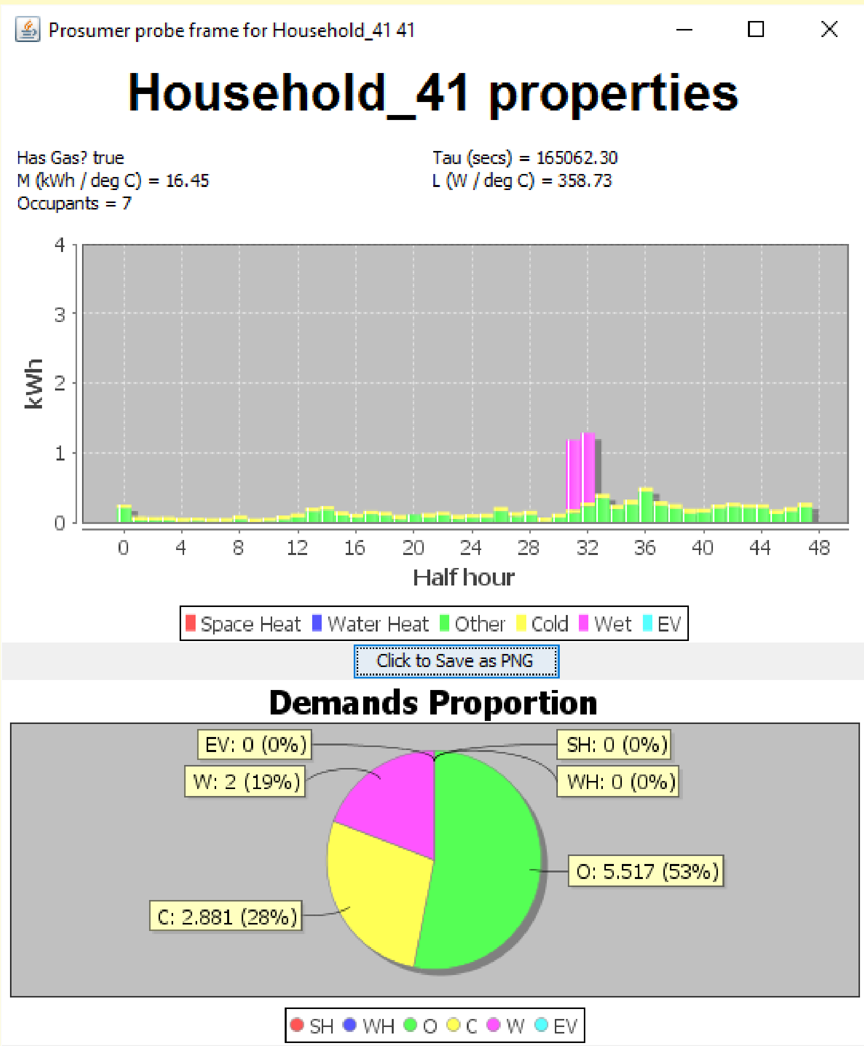
- Single SWELL model – for verification against real world data
- As above with differing weather files (to test dependence on location / weather conditions)
- Multiple Energy Local clubs at SWELL scale
- Clubs with no automated control
- Clubs with no electrical heating

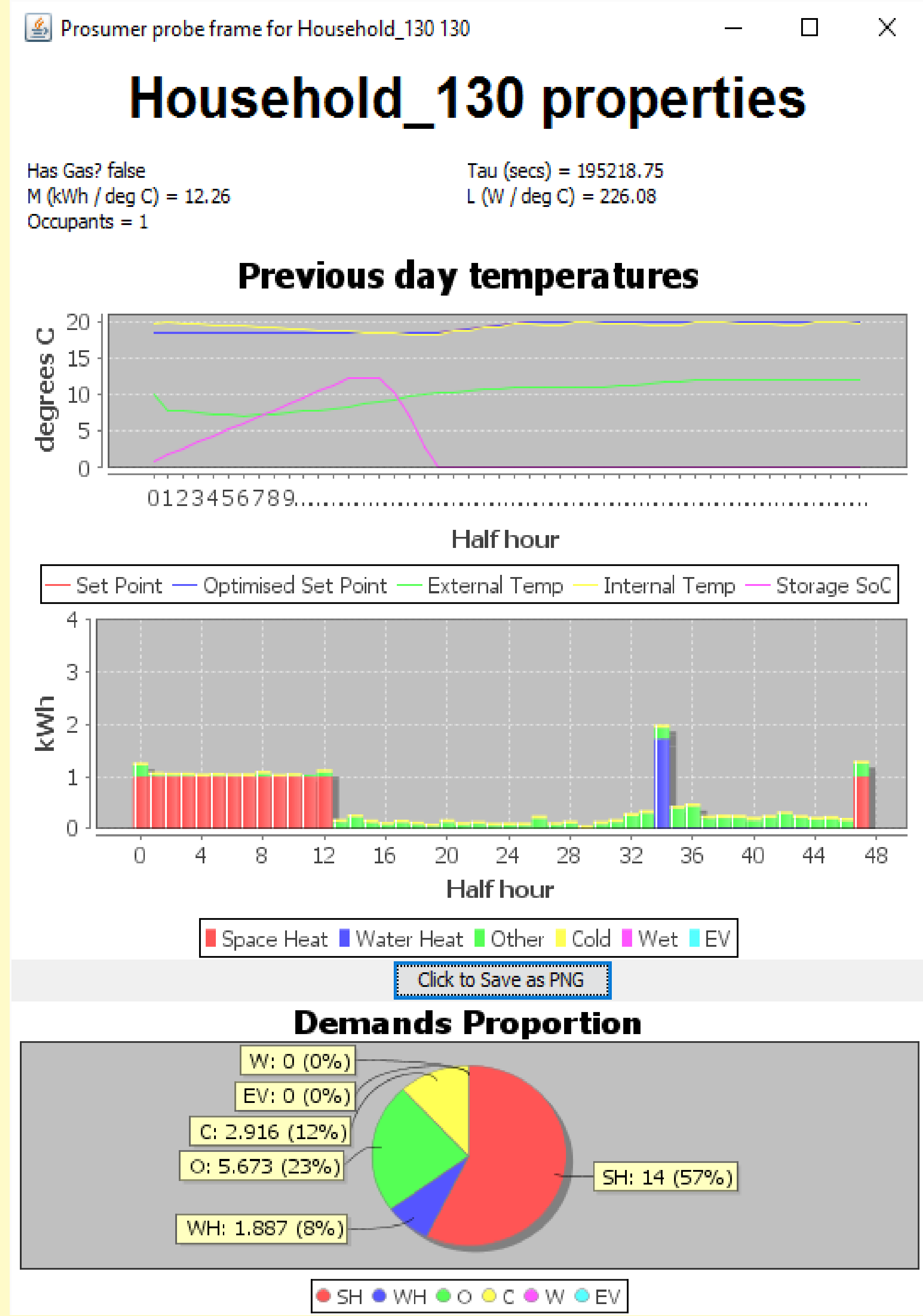
- Prototype model with non-PV generation (e.g. hydro)

Screenshot: Agents & Generation vs. Demand

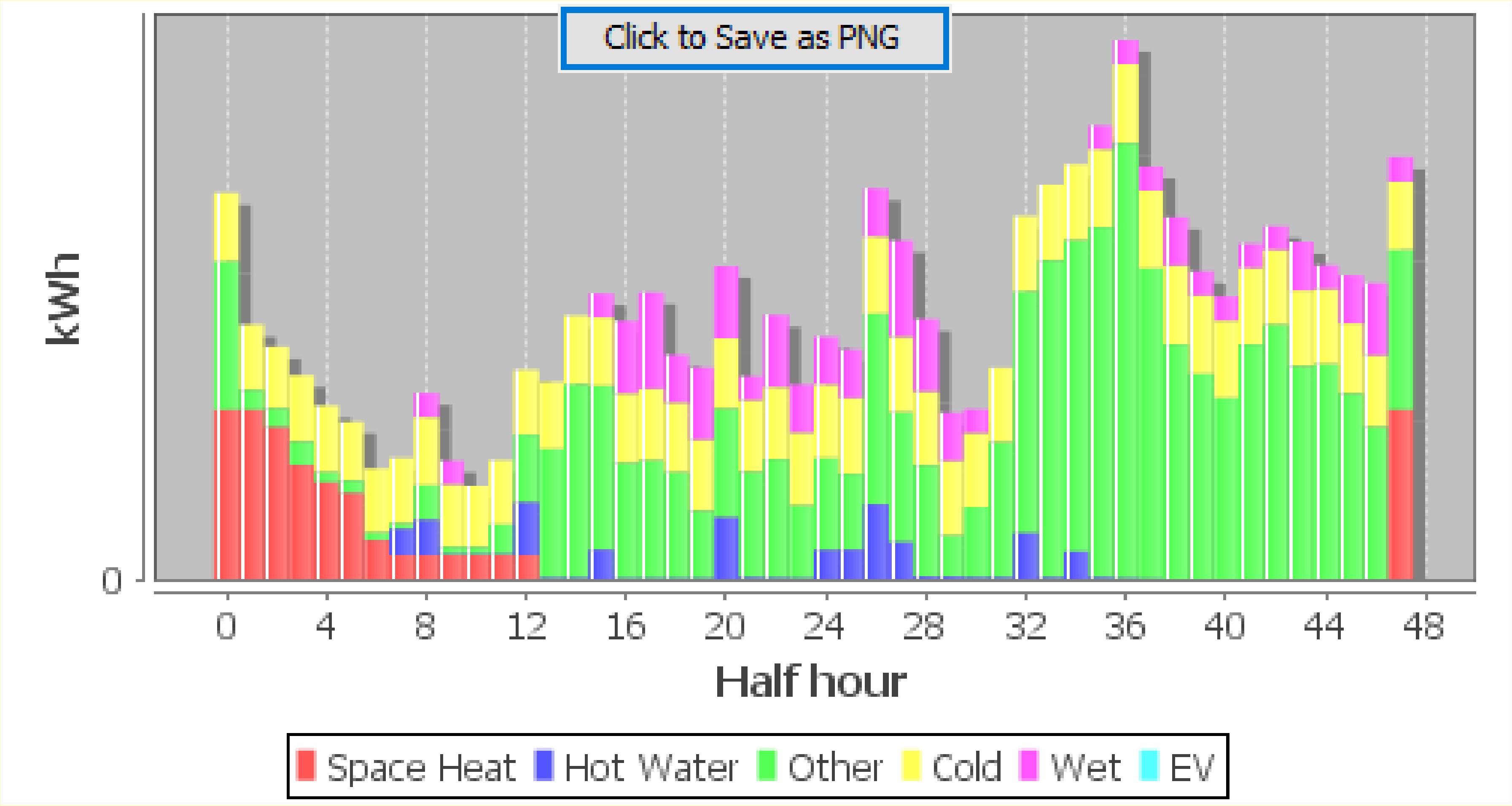


Household demands

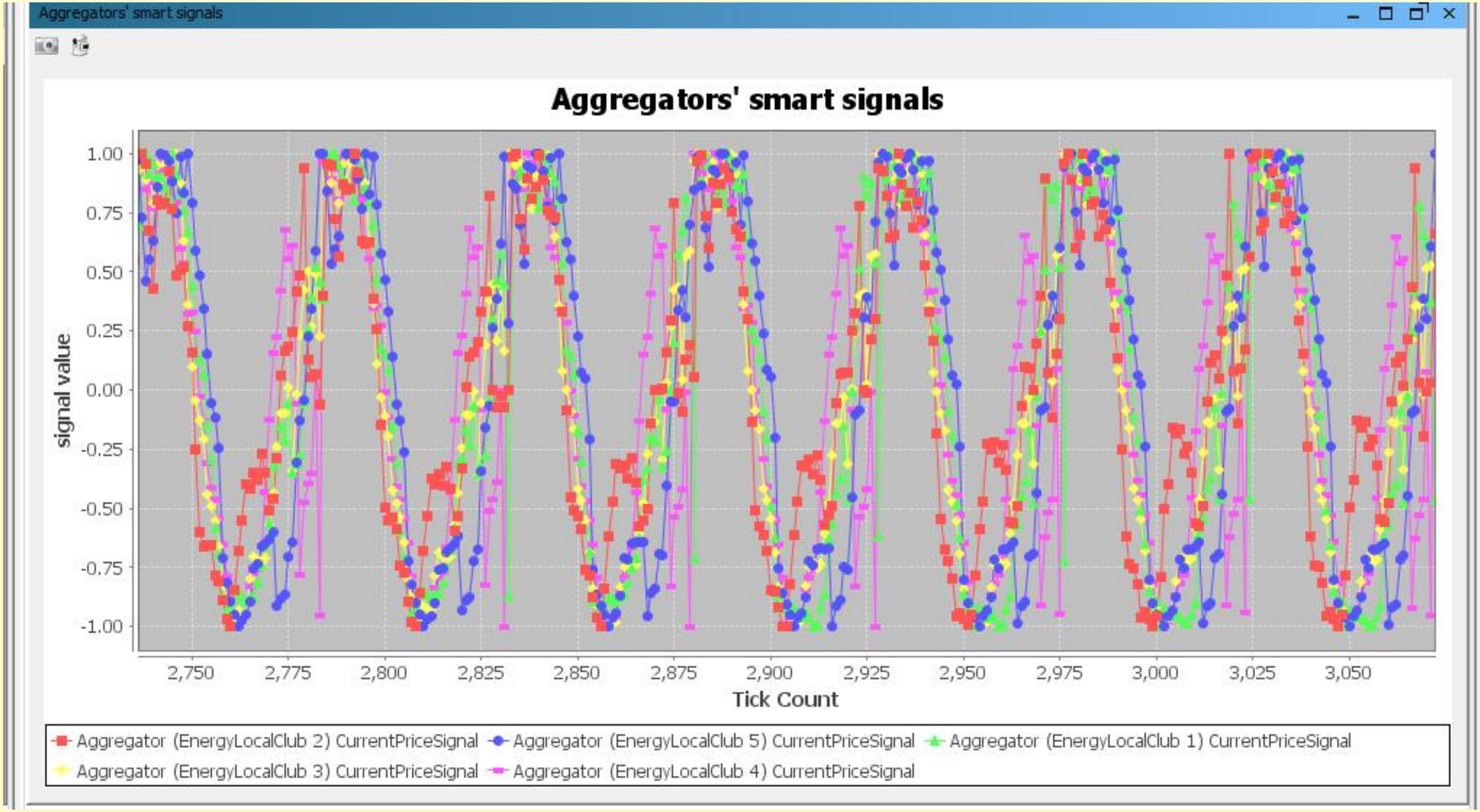




Demand across whole community



Differing but similar signals



Model Outcomes I

- Single SWELL model – verified similar savings and PV share / spill similar to real world data allowing for randomisation in model. (mean~£75/year/participant)
- Energy Local business model delivers across differing weather conditions (i.e. different local generation).
- Business model delivers benefit to participants engaging in desired behaviour – on average all benefit.
- Rewards people's existing "good behaviour", encourages some shifting.
- Most participants benefit – occasional users do not – again as per trial.
- Quantitatively, heating (space and water) delivers most, but other shifts contribute.

Model Outcomes II

- With multiple clubs, if the model is allowed to evolve its own price signal, the signal is similar but unique to each mix of demographics / appliance ownership
- Trade off is needed – practicality
- Global optimum (i.e. considering practicality, ease of interpretation for participants and supplier costs in the optimisation) is different to the modelled optimum for each EL club
- Essentially the age-old local vs. global optimisation issue.
- To some extent mitigated by using manual only shifting and a fixed tariff

Ongoing work

- Publish results for scenarios
- Report quantitative outcomes of model under differing scenarios (demographic, multiple size / location and differing ownership / generation mix)
- Consult with energy suppliers about outcomes from trial and modelling

Conclusions

- Legacy electrical heating is a largely ill-controlled, untapped energy storage vector.
- Better control is possible, saving householders money on average and using local generation.
- Initial scenario modelling indicates that this result is robust to different generation mixes and weather.
- Demographic mix influence on demand shape must be further investigated.
- Modelling shows that different clubs would ideally evolve different signals.
- Pragmatic concerns mean a “good enough” tariff across clubs may be necessary.

Implications

- Smart control of legacy electrical heating for demand shaping is possible.
- Local balancing of embedded generation with storage heating demand is promising.
- Energy Local club business model is viable
  - New scheme (Cyd Ynni) now in progress
- Stable, predictable local consumption of renewable generation is possible.
- Potential to offer locally balanced demand to grid.
- Encouraging community energy use as a policy instrument for use of distributed renewables shows promise.

Comments?

Questions?

Thank you!

References

- [1] DECC, "Digest of United Kingdom energy statistics 2014 (DUKES)," Department for Energy and Climate Change (DECC), London, Jul. 2014.
- [2] Department of Energy and Climate Change (2015). Community Energy Strategy Update. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414446/CESU_FINAL.pdf
- [3] Seyfang, G., Park, J.J., Smith, A. (2013). A thousand flowers blooming? An examination of community energy in the UK. Energy Policy 61 977-989.
- [4] Strbac, G, Konstantelos, I., Aunedi,M., Pollitt, M., Green, R. (2016). Delivering future-proof energy infrastructure. Report for National Infrastructure Commission. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/507256/Future-proof_energy_infrastructure_Imp_Cam_Feb_2016.pdf
- [5] Boait, P.J., Snape J.R., Darby, S.J., Hamilton, J., Morris, R.J.R. (2016), Making Legacy Thermal Storage Heating fit for the Smart Grid, *Energy and Buildings*
- [6] P. J. Boait, J. R. Snape, B. M. Ardestani, (2013) Accommodating renewable generation through an aggregator-focused method for inducing demand side response from electricity consumers, IET Renewable Power Generation 7 (6) 689-699.

Survey analysis: General reflections and thoughts (n=21)

- Mainly positive, some suggestions for future
- Ongoing communication, quick response time and potential scale up of the project has been appreciated by the participants.
- Learning about consumption and shifting usage has happened on a number of levels, from those with minimal prior knowledge about energy efficiency, to those with most professional knowledge.

'it's an amazing thing and I'm really really pleased to be able to contribute. It's something that I really do support and engaged by, [#13]

'As a lifetime electrical engineer, it has proved very intriguing how a slight change in home power use can make significant changes to a pensioner's budget and encourage my continued interest in my chosen discipline.' [#27]

'I think the team are fantastic, lovely ... the efforts that they've made are just wonderful, kit took me a little while to register that I should be trying to change my habits a bit more. Even a supposedly conscious person it took time to register fully' [#14].

Influence of SWELL project on day to day habits of electricity usage (n=37)

- **Yes, SWELL has influenced (31):** Range of activities
  - Constricted by working routines / families
  - key information regarding wet appliances put into action
  - Some cooking activities shifted

'to look out the window and see if the sun's shining, and think 'actually I could leave the washing until tomorrow if its pouring down with rain. I would never do that before, but because of this trial happening, I've tried to get myself more conscious about it.' [#15].

: *'Sometimes opting to microwave or grill instead of using oven.'* [#35]

- **No, SWELL hasn't influenced (6**): using energy efficiently already, generating electricity with solar PV, having young family over.

"when we've got the grandchildren over which is regular at clockwork, you can't be stingy with electricity and gas' [#7].

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