ENERGY LOCAL, A BUSINESS MODEL FOR LOCAL ENERGY COMMUNITIES - CONCEPT AND OUTCOMES

Peter BOAIT
De Montfort University – UK

Robin MORRIS
Energy Local CIC - UK

ABSTRACT

Community energy business models have become challenging as renewable energy subsidies are withdrawn. We describe the regulatory niche, operational systems and practical benefits of a novel approach allowing consumers to actually consume local generation supported by demand response technology.

INTRODUCTION

Community energy initiatives are widely recognised as a valid and useful response to the challenges of climate change, energy security, and energy affordability. The UK government published a Community Energy Strategy in 2014, updated 2015 [1], aimed at encouraging both supply and demand side projects in the challenging environment of the complex UK electricity system. Here we describe a business model and supporting technology designed for communities of electricity consumers whose common factor is that they reside on the same segment of the local electricity distribution network, typically the same low voltage (LV) network. An assumption of the model is that there is some distributed low carbon electricity generation on the shared LV network. This can take any of the common forms such as solar photovoltaics (PV), wind generation, combined heat and power (CHP) or micro hydro. The incentives from the business model are framed to work synergistically with the technology and community engagement to empower participants to reduce their cost of electricity through three mechanisms:

- adapting demand to make use of low cost local generation wherever possible;
- avoiding use of non-local electricity at high cost times such as early evening;
- reducing overall consumption of electricity.

We report results from a practical trial of this concept including a comprehensive combination of features and demand response measures not previously tested in the UK. These were:

- a time-of-use tariff with a static baseline and a day-ahead dynamic adjustment reflecting the predicted availability of local PV-generated electricity;
- a web-based display of the current tariff and consumption on user's smart phones, tablets, etc.;
- technology to automatically schedule loads at an optimum time with respect to the tariff;
- exploitation of domestic energy storage in batteries and thermal storage heaters;
- regular feedback on the financial savings for individual users and the participant group as a whole;
- a sustained program of engagement aimed at retaining user interest and obtaining their feedback.

THE BUSINESS MODEL

The UK Balancing and Settlement Code (BSC) includes a concept known as the "Complex Site". This was conceived to apply to situations such as an industrial site with distributed generation present and multiple industrial consumers. It allows the local generation to be allocated to local consumption, with the aggregation of the generation and consumption being treated as export or import for the site as a whole. It requires half hourly metering of all connections and the processing through settlement of these half-hourly meter readings, which is currently not possible with UK domestic "smart" meters. This process is described in rather legalistic terms in the extract from the BSC at [2].

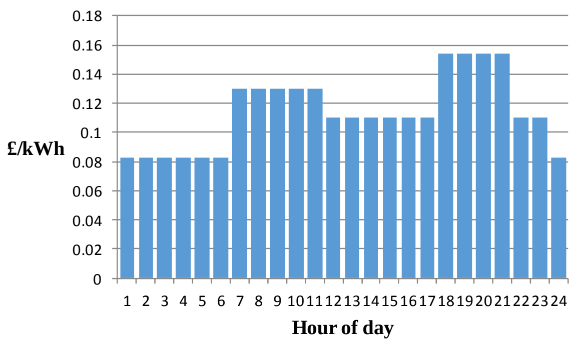

Figure 1. Time of day dependent tariff

Energy Local has worked with metering and retail electricity supply partners to devise an interpretation of this process which allows a group of domestic consumers to take power from one or more small scale generators that share the same LV network. The consumers pay a preferential tariff for the locally generated electricity that they use. The balance of their consumption is purchased from a retail supplier at a time-of-day dependent tariff. This supplier manages payments to the generator for matched power and presents a consolidated bill to each consumer in the group. This supplier also purchases any generation that is not taken by the consumers in the group under a conventional power purchase agreement (PPA). The time of day tariff employed for the trial is shown in Fig.1

A unique feature of this business model is that it overcomes a legal constraint on financing local generation by forming a community co-operative. UK financial regulation requires that the investing members of a co-operative must either be workers in, or consumers of, the commercial product of the enterprise. This is to avoid the regulatory concessions available to co-operatives being exploited by purely speculative investment offers. Where the whole output of a generator is sold to an electricity supplier through a power purchase agreement, under a recent UK regulatory clarification [3] the investors in the generator cannot be considered consumers. This model opens up access to locally generated power to members of a co-operative. The enhanced value of the locally-consumed power improves the investment case for generation.

The allocation of this local generation to local consumers requires a suitable fair algorithm for periods when generation is less than the aggregate demand. This algorithm finds for each half-hour a "fill level" L chosen such that for each of n consumers with demand e_i in the half hour greater than L, L kWh can be considered supplied from the generation A kWh in the half hour, and for those remaining m consumers with demand e_j less than L, their demand can be fully met from A, with L also satisfying:

$$A = nL + \sum_{j=1}^{j=m} e_j \quad (1)$$

For the initial trial described in the next section the tariff rates shown in Figure 1, and the rate for local generation of 6.5p/kWh, were implemented as "virtual tariffs" to mitigate risk and comply with UK restrictions on the number of tariffs a supplier can offer. The participants were given vouchers for the supermarket chain operated by the supplier equal in value to the savings they made on this tariff relative to their actual current tariff. This also avoided any need for participants to change supplier. For the commercial trial described later, similar tariffs were fully operational with half-hour metering and settlement in place.

THE SWELL[1] TRIAL

Demand response and metering system

A total of 48 households were recruited to this trial which took place Oct 2015-Feb 2017. Of these, 14 had rooftop PV amounting to 45kWp providing the local generation, while 9 that did not have PV were equipped with 2kWh batteries. To execute the metering required for this scheme and enable the participants to make best use of the local generation and time-of-use tariffs a "smart" metering and control unit was installed in each household. Branded "Hestia" this unit provided a display of the tariff rates on any convenient device connected to the household broadband, but modified the displayed rates with a dip during the middle of the day that reflected approximately the amount of local PV generation predicted to be available based on the overnight local weather forecast. It also provided displays of electricity consumption and generation over the last 24 hours for the household, the participant community as a whole, the aggregate community PV generation, and the PV generation for the household for those so equipped. To provide these displays metering data at one minute intervals was collected and processed in a central database. A simplified view of the system is shown in Figure 2.

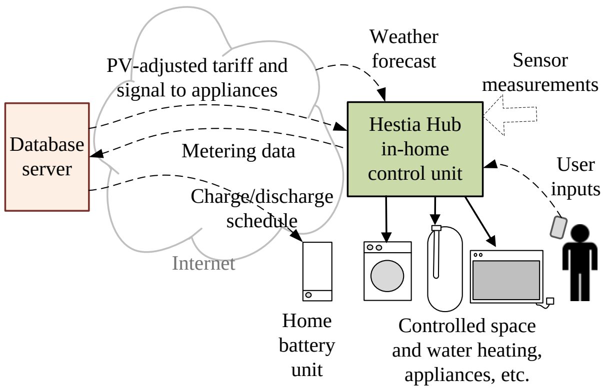

Figure 2. SWELL system diagram

The Hestia control unit also performed automatic demand response for controllable appliances as illustrated in Figure 2. Six of the participating dwellings had space heating provided by electrically-heated thermal storage heaters and hot water from an immersion-heated tank. Charging of these useful thermal energy stores was controlled such that user comfort requirements as expressed on the Hestia user interface were prioritised, but was otherwise optimised against a tariff-dependent signal from the database server that ensured cost effective use of local generation and the time-of-day tariff while preventing peaks in aggregate demand at tariff boundaries by randomizing dispatch of loads. This signalling and optimization methodology has been described in a previous CIRED paper [4]. The peaking risk that is mitigated has been identified in many simulation studies e.g. [5],[6].

All of the participants were given a "smart plug" for which the on/off status could be radio-controlled via a user interface provided by the Hestia unit. This allowed users to set a time window within which an appliance powered via the smart plug should operate, and the

1 This acronym refers to the Energy Local model in the cluster of villages Shrivenham, Watchfield and Longcot, where the trial took place.

required operating duration. If some scheduling flexibility was available from the difference between the time window and the operating duration, the Hestia selected an optimized dispatch time using the demand response signal. The batteries were scheduled to charge during low tariff periods and discharge during the early evening high tariff rate period, with the objective of improving the benefit these households obtained from the tariff scheme.

Trial results-financial

The financial benefit of the trial to the participants over a year is shown in Figure 3. This accrued in three different ways; to all participants from the time-of-day tariff, to the participants without PV from consuming the export PV generation from those with PV at the favourable rate of £0.065/kWh, and those with PV, from the additional export payment of £0.065 for each export kWh matched with consumption, and £0.055 for each kWh not matched so considered as taken up by a PPA.

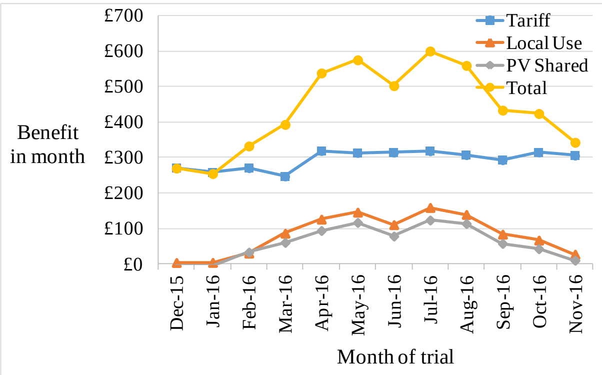

Figure 3. Financial benefit to participants

Over the year of trial operation, out of the total PV generation of 43 MWh from the 14 generators, 18 MWh were used within the generating households, and 26 MWh were available to share with other participants. Of this available total, 22 MWh were matched with consumption using the algorithm described earlier, and the balance of 3 MWh was allocated to the PPA. The generation tariffs gave an improved financial return simulated through the credit vouchers of about 80% to generators (£719 in addition to £868 from 50% deemed export feed-in tariff at £0.040/kWh making a total of £1587). The generation matched with consumption represented about 9.5% of the total electricity consumed (c. 233MWh) by all the participants during the year.

Trial results – demand response

The most substantial demand response came from six electrically-heated homes. They presented a special case in that they were already using a time-dependent tariff known as Economy 7. This comprises a low rate for 7 hours overnight of about £0.07/kWh and a higher day rate of about £0.016 typically used, as in the present case, with thermal storage heating and domestic hot water tanks that can be charged at the low rate. The Hestia control system responded to a signal which moved some of the heating demand into the middle of the day to take advantage of the local generation and lower mid-day tariff. The controls also improved comfort through a more precise matching of stored thermal energy to the weather-dependent heating demand. The resulting shift in distribution of demand is illustrated in Fig. 4 which shows the increased heating demand during the day. Under Economy 7 demand would have been restricted to the first 7 hours of the day. A comprehensive report focused on the performance of the heating controls is provided in [7].

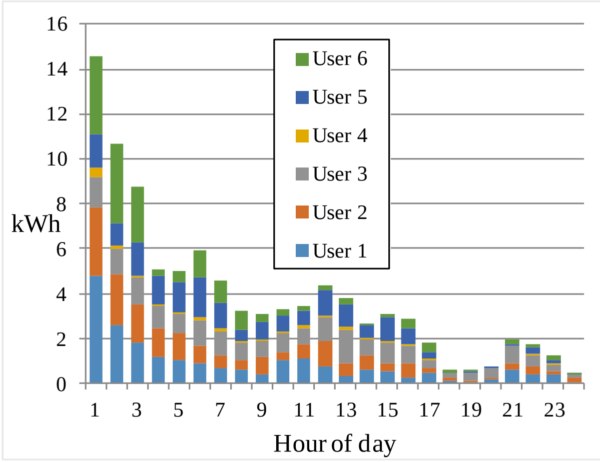

Figure 4. Profile of heating demand (Feb. 16)

To examine the range of individual household responses, the average demand in each of the six tariff periods shown in Fig. 1 was calculated for each household for October-December 2015 and for the same period in 2016. The correlation between changes in demand in each tariff period, and the tariff rate was then tested, with the hypothesis that demand would have changed over the year in inverse proportion to the tariff as consumers became accustomed to a time-of-day tariff and adjusted their demand accordingly.

Table 1. Correlation of change in demand over a year with time-of-day tariff.

Group attribute	No. in group	Responders	R^2 range for responders
Controlled electric heating	6	5	0.15-0.26
PV generator	14	11	0.13-0.70
Battery storage	8	7	0.23-0.82
All other participants	19	4	0.16-0.67

The results for different participant groups are shown in Table 1. A participant was counted as a "responder" in the table if a negative correlation was observed between change in demand and tariff rate with an R^2 value greater than 0.1. The much greater proportion of responders among participants with some additional technology that reinforces their engagement is evident. Note all the groups in Table 1 are independent i.e. there is no overlap of membership.

FOLLOW-UP PROJECTS

The success of this trial has led to a first fully commercial implementation of the concept for a community in the small town of Bethesda, North Wales [8]. This is based around a 100kW micro hydro generator. 100 consumers have been recruited, who pay £0.07/kWh for matched use of local generation, and a small charge for membership of the consumer co-operative club. Any electricity not supplied by the hydro is charged according to a time-of-day tariff similar to that in Fig. 1. Because the output of this generator varies seasonally, power availability is signalled to users. Fig. 5 shows the proportion of each user's power matched to low cost local generation, with an average of 65% over the year of operation.

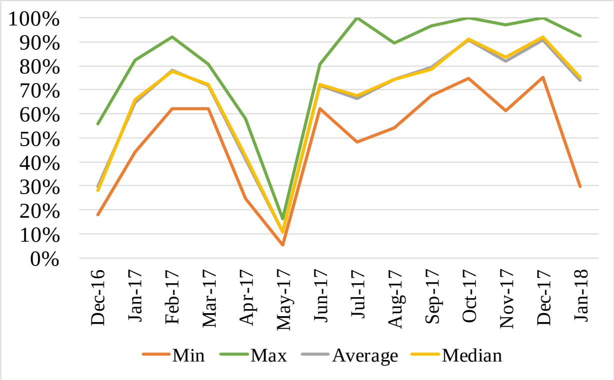

Figure 5. User demand matched to local micro-hydro

Energy Local is now developing a "starter pack" of processes and documentation [9] with follow-up support, allowing social enterprise clubs to be formed and the model implemented wherever appropriate generation, network configuration and community enthusiasm exist. New micro-hydro clubs are in progress elsewhere in Wales, and PV-based in London and Gloucester.

CONCLUSION

Community energy schemes can only survive and prosper by providing benefits to the whole electricity supply chain. This concept offers value for the distribution network operator, retail supplier, small generators, and the consumer. By establishing and extending its regulatory niche we aim to bring it into widespread use.

Acknowledgements

The authors would like to thank the Engineering and Physical Sciences Research Council (EPSRC) and Innovate UK for providing financial support to the SWELL project (EP/G000395/1), also part funded by Energy Local (Development) Ltd, Exergy Devices Ltd, Moixa Technology Ltd, Westmill Sustainable Energy Trust, and Co-Operative Energy who provided the supermarket vouchers to participants reflecting their benefit from the simulated tariffs..

REFERENCES

[1] Department of Energy and Climate Change, (2015), *Community Energy Strategy Update*, https://www.gov.uk/government/publications/community-energy-strategy-update

[2] Elexon Ltd, 2018, *Shared SVA Meter Arrangement of Half Hourly Import and Export Active Energy*, https://www.elexon.co.uk/csd/bscp550-shared-sva-meter-arrangement-of-half-hourly-import-and-export-active-energy/ .

[3] Financial Conduct Authority, 2015, *Guidance on the FCA's registration function under the Co-operative and Community Benefit Societies Act 2014*, https://www.fca.org.uk/publication/finalised-guidance/fg15-12.pdf

[4] P. Boait, B. Ardestani, R. Snape, 2013, "Levelling of heating and vehicle demand in distribution networks using randomised device control", *Proceedings 22nd CIRED, Stockholm 10-13 June*, Paper 0140.

[5] S. D. Ramchurn, P. Vytelingum, A. Rogers, N. R. Jennings, 2011, "Agent-Based Control for Decentralised Demand Side Management in the Smart Grid", *Proc. of 10th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2011), Taipei* , pp. 5-12.

[6] A. Roscoe, G. Ault, 2010, "Supporting high penetrations of renewable generation via implementation of real-time electricity pricing and demand response", *IET Renew. Pwr.Gen.* vol. 4(4), 369-382.

[7] P. Boait, J. Snape, S. Darby, J. Hamilton, R. Morris, 2017, "Making legacy thermal storage heating fit for the smart grid", *Energy and Buildings*, vol 138, 630-640.

[8] BBC news, 2016, "Bethesda energy club shares hydro power in UK first". http://www.bbc.co.uk/news/uk-wales-38236414

[9] Energy Local, 2018, "Making energy work for you", http://www.energylocal.co.uk/ .