ETTRICK AND YARROW ACTIVE NETWORK MANAGEMENT PROJECT

Final Project Report

Report by Community Energy Scotland

COMMUNITY ENERGY SCOTLAND

Community Energy Scotland (CES) is a Registered Scottish Charity and company limited by guarantee established in 2007. Our main charitable objectives are community development, environmental protection and the alleviation of poverty. Our mission is to build confidence, resilience and wealth through sustainable energy development at community level.

CES has been at the heart of community renewable energy development for over a decade and with our substantial experience we are best positioned to offer advice and support to Scotland's communities. As Scotland's first, and only, national charity dedicated to supporting community renewable energy development, we have firmly established ourselves as impartial, independent specialists.

LOCAL ENERGY ECONOMIES

Over the last few years CES has led the development of the 'Local Energy Economies' (LEE) concept in Scotland. The idea is simple – to use as much locally-generated renewable energy locally, retaining its financial value in the local community, minimising transmission losses and substituting it as much as possible for carbon-based fuels in transport and heating. As this decentralised energy model is not the way the UK energy system works at present, there are plenty of policy, regulatory, technical and financial challenges to overcome. We are systematically addressing these through novel partnerships with community groups and others and this document is one part of the overall process.

Local Energy Economies

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Empowering Communities

Local Energy Economies

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EXECUTIVE SUMMARY

This project explored the scope for a community owned Active Network Management scheme in the Ettrick and Yarrow valleys. This would potentially have combined new local renewable generation with flexible heat, electricity and transport loads in the area, to reduce energy imports and exports, and maximise local financial benefit. Surveys and electrical monitoring were undertaken to inform the scale of potential controllable local load available, which is in the region of 500kW and 100MWh/year at present, and could potentially grow tenfold as heat and transport are electrified. With present expenditure in excess of £2m/year on fuels and electricity in the area, there is significant scope for local savings arising from electrification and flexibility. It has not been possible to move to the demonstration phase of the project as originally intended, and it has also been shown that at present there is little scope for a financially viable wind or hydro scheme in the area. However, the preparatory work and local education undertaken through this project will place the valleys in a strong position to benefit from flexibility opportunities as they arise in the future.

INTRODUCTION

Community Energy Scotland (CES) has been commissioned by Ettrick and Yarrow Community Development Company (EYCDC) to produce a final report for the SP Energy Networks Green Economy Fund project GEF0035, Ettrick and Yarrow Smart Grid Demonstrator, which is also part-funded by the Scottish Government's CARES scheme.

BACKGROUND

Ettrick & Yarrow Community Development Company (EYCDC) wishes to install community owned electricity generators using renewable resources for the benefit of the community and to tackle climate change and develop the area in a responsible manner. They have investigated various possibilities but possible transmission level grid constraints have prevented progress. Use of a community Active Network Management (ANM) or 'smart grid' system has been suggested as a way to not only enable new generation to be connected onto the local distribution circuits but also improve the efficient use of this valuable resource.

PROJECT CONCEPT AND METHODOLOGY

This project aimed to develop community understanding of 'smart' energy by implementing a small-scale, community-led ANM scheme in the Ettrick and Yarrow valleys. The primary aim was to strengthen the business case for new renewable generation in the area. This strengthening could have arisen in several ways; through reducing direct connection costs, or the need for local grid reinforcement; potentially through direct supply to local consumers, if opportunities were identified for private wire or 'behind the meter' generation; and ultimately (once regulation permits this) by allowing for local supply of energy from generation to consumers in the area through SPEN's network, at mutually beneficial prices.

The rationale for exploring a local ANM solution instead of 'traditional' solutions to grid barriers was that previous indications were that any significant generation in the valleys would probably require a dedicated new 11kV line, several kilometres in length, back to the Selkirk Primary Substation. This would be extremely expensive, with a previous study estimating a cost of at least £320k for a 100kW connection. This option might also have triggered the requirement for a Transmission Statement of Works (causing further delay, and potentially additional wider reinforcement costs), and there would have been little to no community benefit in terms of linkages to local demand, meaning no clear future scope for local supply at reduced cost for consumers. Another approach would have been to simply scale new generation to a level where new grid infrastructure is very minimal; however, this would have significantly limited the scale of potential yield, carbon savings, and income generation, as well as reducing any scope for local supply. Exploring an ANM solution was therefore a prudent approach to maximise local benefit.

The project had a number of objectives, including;

- Education and awareness-raising around changes to our energy system
- Demonstration of electric vehicle use and benefits
- Demonstration of smart electric storage heating
- Improving community understanding of ANM systems and how the community could implement one locally
- Working with SPEN to better understand grid constraints in the valleys

- Building a better understanding of local energy demand through surveys and monitoring
- Using data gathered to design an ANM system and associated controls
- Revisiting potential for community owned generation at various sites
- Setting up a demonstrator ANM system incorporating smart charging of electric vehicles and storage heaters
- Development of an updated business plan for new community generation based on an ANM connection
- Documenting the outcomes from piloting a community-based ANM system.

In order to achieve these objectives, various activities were carried out. A steering group was established, involving representatives from EYCDC, SPEN and CES. A Smart Energy Officer was recruited to lead on data gathering and local information dissemination. A number of local events were organised to spread the word about opportunities for involvement in the project, and about the changes happening in the energy system. Surveys of local businesses and households were carried out in order to ascertain present energy use across electricity, heating and transport, as well as to gauge interest in local flexibility opportunities, such as demand-side management of heat, and flexible EV charging or vehicle to grid (V2G) technologies.

Electricity monitors were also installed in a number of properties to gain more detailed information on energy use at different times of day and in different seasons. This also provided useful data on local system voltage, which might be a constraint for future generation. SPEN also installed monitoring on local low-voltage (LV) transformers, which has provided some additional data around the scale of local loads, relevant to the scope for future flexibility.

An electric minibus (40kWh Nissan E-NV200) was procured by EYCDC as part of the project, to act as a demonstration vehicle locally, as well as providing valuable local community transport services. Two chargepoints are still to be installed for this vehicle. It had also been planned to install some new storage heaters in a community building. The next stage would have been to progress on to the design and implementation of the ANM demonstrator, which would have demonstrated the deployment of the flexible loads (EV chargers and new storage heaters) in response to grid conditions, to enable a simulated new generator to connect. This would have provided valuable learning on how to utilise relatively simple and affordable 'off-the-shelf' components to construct an ANM central control system and local load controllers in a small-scale context, as well as integration with the DSM elements.

However, the lead partner (EYCDC) decided not to progress to this next design and demonstration phase. The line monitors originally intended to be placed on SPEN's 11kV lines through the valleys (both to monitor demand for design purposes, and to provide signals to the ANM controller) could not be installed by SPEN, as they have neither the policies nor qualified staff to place them on overhead lines at present. Without these live signals, the ANM demonstration would have involved simulated constraint signals or grid data instead. Additionally, SPEN indicated that as well as the known transmission constraints in the area, it is very likely that voltage rise issues will limit the opportunity for community generation in the valleys. For these reasons, EYCDC decided it would not be worthwhile moving on to the ANM demonstration phase, or to look in more detail at the scope for wind, hydro or solar in the area. The project was therefore curtailed prior to the simulated demonstration phase. This report will detail the findings from the elements of the project that have been completed.

DATA SPACE

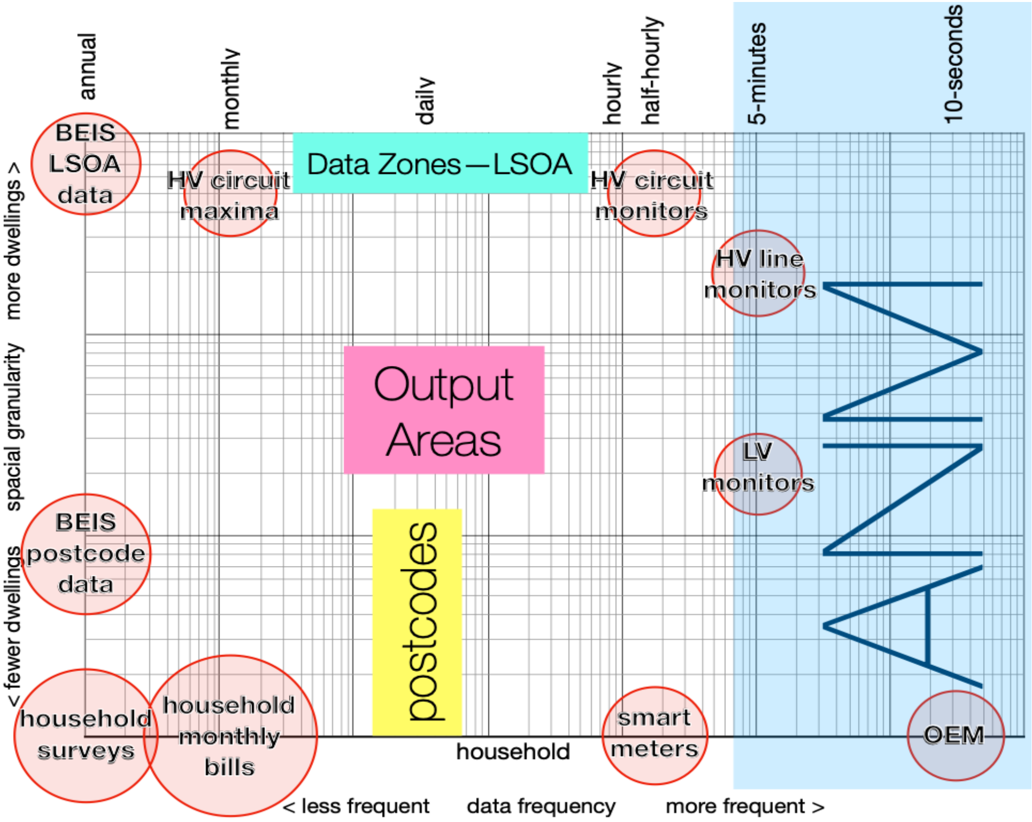
Various data sources were used in this project and together they build a picture of electricity consumption across the area. These sources range from annual data for Census Data Zones to 10-second interval measurements of consumption for individual households.

Annual data is readily available and useful to understand the overall flow of power; monthly data gives insight into seasonal variations and half-hourly and more frequent data brings understanding of how individual loads are switched and their impact on the system.

The chart below shows the various data available or discussed; the size of the 'bubbles' varies according to the number of data subjects, which ranges from a handful to hundreds. Please note that both axes and bubble sizes are logarithmic to allow representation of a wide range of granularities.

The blue area on the right of the chart identifies those data sources that are appropriate for inclusion within an ANM scheme. This includes data frequencies from 10-minutes and any area from individual households to the whole network under consideration.

Postcodes, Output Areas and Data Zones are represented to indicate the number of dwellings that may be included in each set. (Their positioning on the frequency scale is immaterial.)

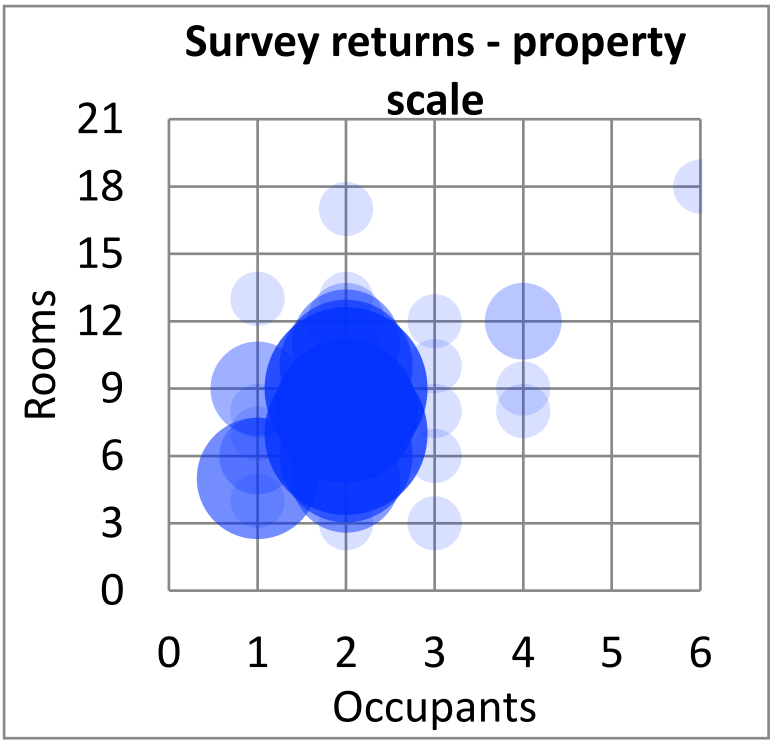


HOUSEHOLD SURVEY

Overview

The household survey was conducted by Stefan Murray, the Project Officer from May to October in Ettrickbridge, Broadmeadows, Yarrowford, Upper Ettrick and selected households in other parts of the valleys. A total of 79 surveys were completed covering different house types and some businesses. This represents about a sixth of the total properties in the valleys. The surveys were curtailed at this point.

All properties were classified into predetermined categories, which were subsequently whittled down to seven so that the results can be scaled up across the total array of properties in the valleys. Total figures for the housing stock in the valleys is estimated and therefore any scaled figures in this current report are taken from the survey data for domestic dwellings multiplied by about six to give an indication of total figures for the area.



The addresses visited were selected on a targeted basis with lists of postcode areas being supplied by the Project Manager to the Project Officer. A total of 20 postcode areas were visited; just under a third of the total that define the area. The two most represented postcodes provided almost half the survey responses, one in Ettrickbridge and the other in Broadmeadows and these larger settlements are perhaps over-represented in the results.

Validation

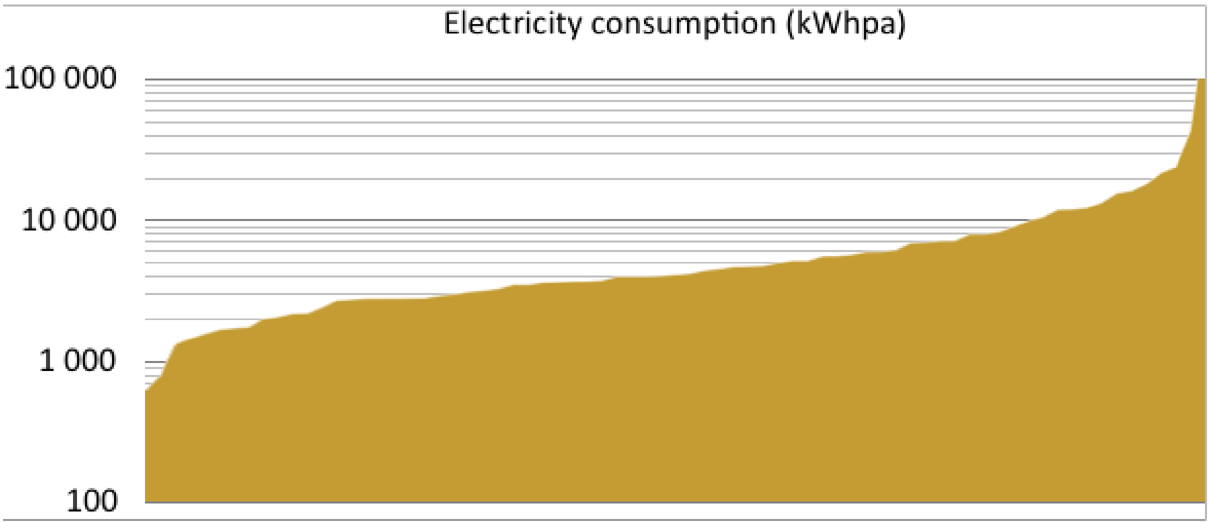
The question is whether the sample households surveyed are representative enough. Electricity data is not available at Output Area level and the two Data Zones covering the area include places outwith the EYCDC area and some parts of the area are not included within the main Data Zones. There are, however roughly the same number of people and households in the excluded and extra areas and the Data Zone data therefore provides a reasonable sense-check for the gathered data.

The two Data Zones consumed 3.2GWh of electricity in 2017 with an average of just over 5MWh per meter. Our dataset recorded a total of 363MWhpa across the 69 non-commercial properties for which data was collected, giving an average of just over 5MWh per dwelling. This suggests that the electricity consumption data at least are representative of the whole population.

Comparing households and dwellings across the survey subjects and the whole area indicates that the surveyed households have slightly more residents than the area average (by about 10%).

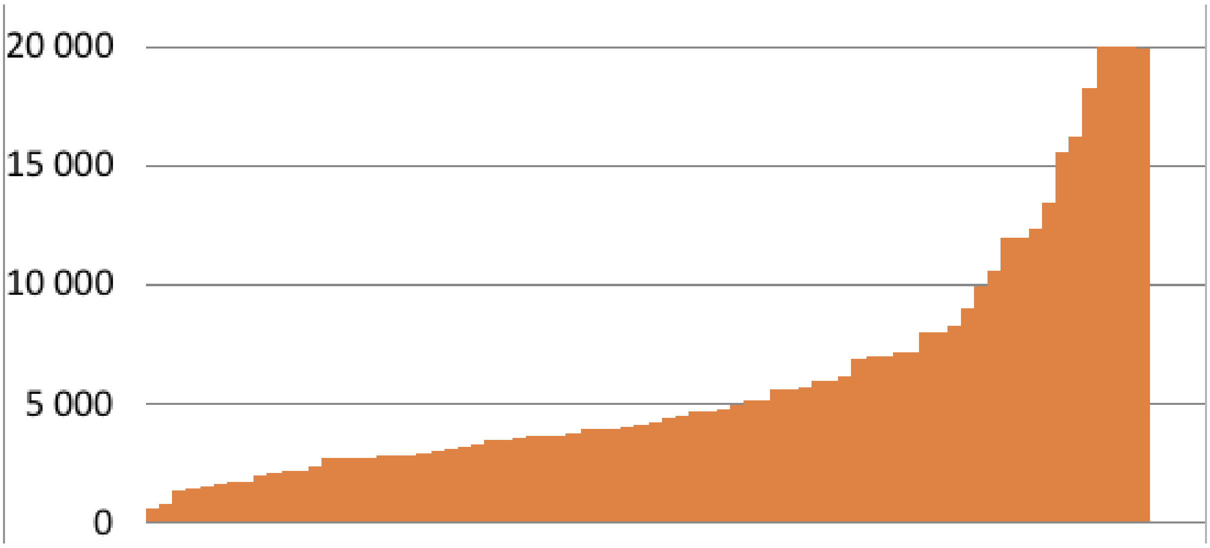
Electricity

Domestic electricity consumption varies widely from less than 1MWhpa to more than 20. This first chart shows all of the survey result (using a logarithmic axis to enable most of them to be shown reasonably. The range is 2½ orders of magnitude and even the spread of domestic properties spans a factor of 35.



Spread of electricity consumption showing a small number of very large users, a significant proportion (~⅕) with particularly low consumption (<2500kWhpa) and a wide spread of consumption up to 20MWhpa.

The second chart shows the same data on a limited, linear scale, the larger consumption figures being truncated at 20MWhpa. The median consumption of this survey is 4000kWhpa and that of the BEIS MSOA data is around 3500kWhpa. There are some dwellings that consume six times as much and some in our sample that consume about one sixth of the median consumption.



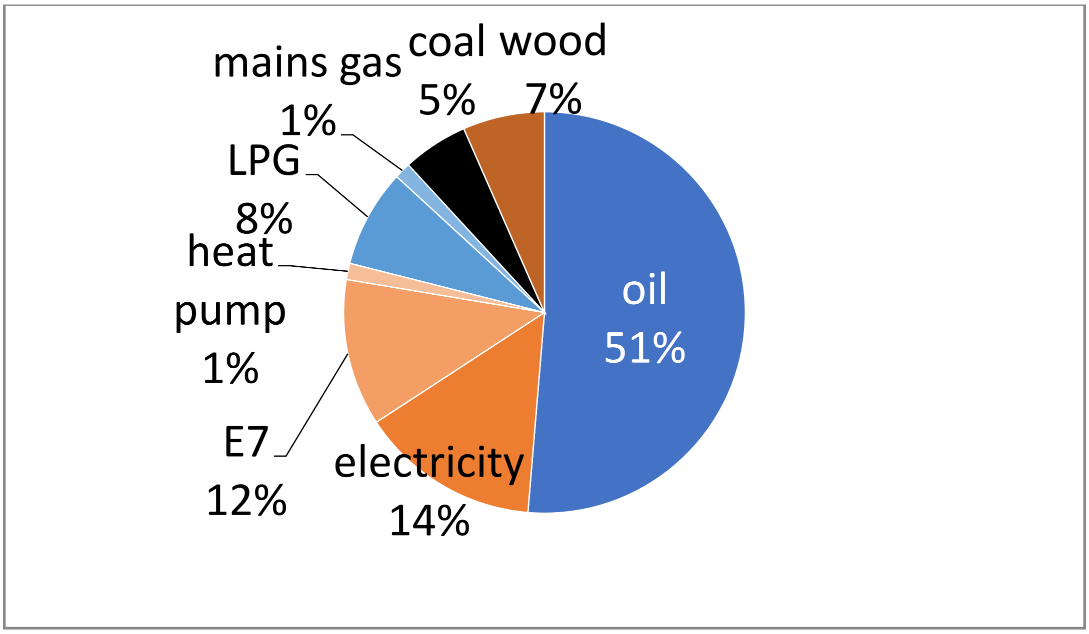
Spread of electricity consumption on linear scale showing the variation of consumption from very low to over ten times the amount. About ⅓ of dwellings consume more than the average.

Heat

The provision of space heating and domestic hot water is by far the largest component of energy consumed within homes, comprising sixth sevenths (6⁄7) of household energy.

Fuels

Heating oils provide over half of the total home energy (or about 60% of the heat requirement). Gas (mainly bottled) and coal provide about a seventh and wood about half of that. The remainder of heat comes from electricity, either through an economy 7 (or similar) tariff or by heaters on a standard electricity tariff.



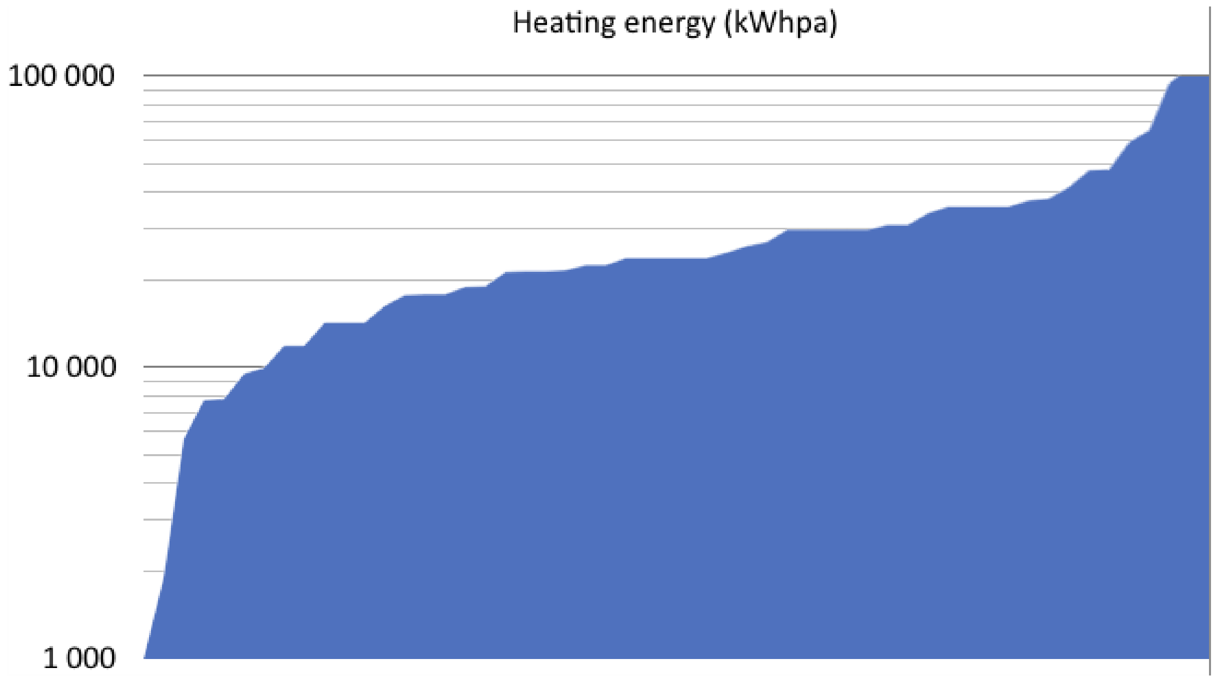
Storage

One in six of the houses surveyed has energy storage of some form and the vast majority of these are heat stores, equally divided between hot water cylinders and storage heaters. The total power of these heaters is in the order of 100kW with several hours of storage available in each installation.

This indicates that already there is about half a MW of electrical storage installed in the valleys with scope to increase this several-fold. The extant stored energy capacity is in excess of a megawatt-hour with potential to be increased to ten times that as people transition away from fossil fuels with heat batteries, and storage of various kinds.

Consumption

The annual data does not reveal any seasonal or diurnal patterns and it is expected that these will be typical of GB with greater consumption during the colder months and in the evenings with the overnight hours having significantly less consumption except for off-peak heating loads.



Spectrum of heat consumption—plotted on a logarithmic scale to accommodate the wide variance

Transport

Regional data show that transport consumes as much energy across the year as homes. Within this survey, the 79 properties had a total of 130 vehicles an average of about three vehicles for every two households. Approximately 860 thousand miles are driven in these cars, vans and other transport each year, consuming over 1GWh of fuel. Depending on actual fuel efficiency achieved, the actual figure could be twice this.

The average mileage for the vehicles included in the survey is only marginally greater than the UK average although the spread is significant and again a logarithmic scale is employed to accommodate the extremes.

Of the 130 vehicles included, only one is an electric and one a hybrid. At least 75 are diesel and 42 petrol vehicles are included within the survey. Two households are without a vehicle.

If the surveyed households are representative of those across the two valleys and the mileage estimates realistic, the data suggest that about a million pounds is spent each year on motor fuel. This expenditure could be quartered and the money kept within the area if electric vehicles were charged from local renewable electricity.

WHOLE-HOUSE ELECTRICITY MONITORS

Background

For any active network management (ANM), measurements of power flows need to be available. These need to happen at various levels including at individual households. Some homes also have PV installations and these generators should be measured separately wherever possible. Survey participants were invited to host a whole-house monitor and these were fitted whenever possible with data aggregated on a cloud platform.

Overview

Open Energy Monitor (OEM) EmonTX units were used with Huzzah ESP8266 wifi modules so that they could link directly to the internet through the home's existing wifi network. Each unit can connect up to four current clamps, enabling three-phase supplies and generators to be monitored. Voltage is measured and room temperature can also be recorded using a separate plug-in sensor.

The monitors were set up to provide ten-second readings, which is sufficient to show brief events like boiling a kettle or heating in a microwave. Each power input was also set up to record accumulated energy, which is more useful when analysing diurnal, weekly and seasonal variations. Voltage is also recorded along with temperature where sensors were installed.

All of the data is uploaded to the OEM cloud service where various calculations are performed, including the accumulated energy feed. The OEM cloud service allows live and historic data to be viewed, graphs to be generated and dashboards of indicators to be built.

Issues

Some monitor installations were not able to be completed due to the distance between suitable wires around which the clamps can fit and mains sockets. Extension leads for the current clamps or mains were used where this was feasible but some sites proved unworkable even with such interventions.

Data is lost whenever the internet connection is unavailable and as well as temporary outages due to service provider problems; some sites went offline due to the owner switching off the telecommunications equipment.

Uses

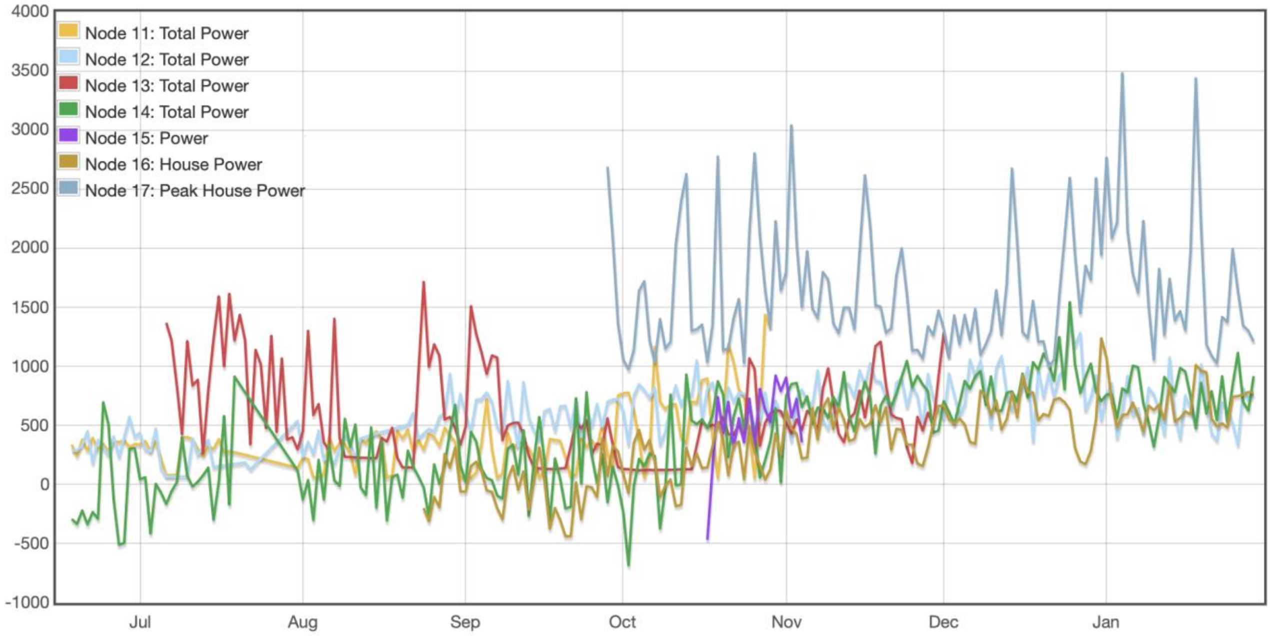
As well as collecting data for the project, hosts are encouraged to view the data for themselves to gain a better understanding of their own electricity use and generation. Each householder was shown how to access the cloud portal to view individual feeds, graphs and historic data.

Where there has been sufficient interest, personalised dashboards were created for individual premises along with the community dashboard which shows the aggregate of all the monitored houses.

Example of domestic monitoring dashboard

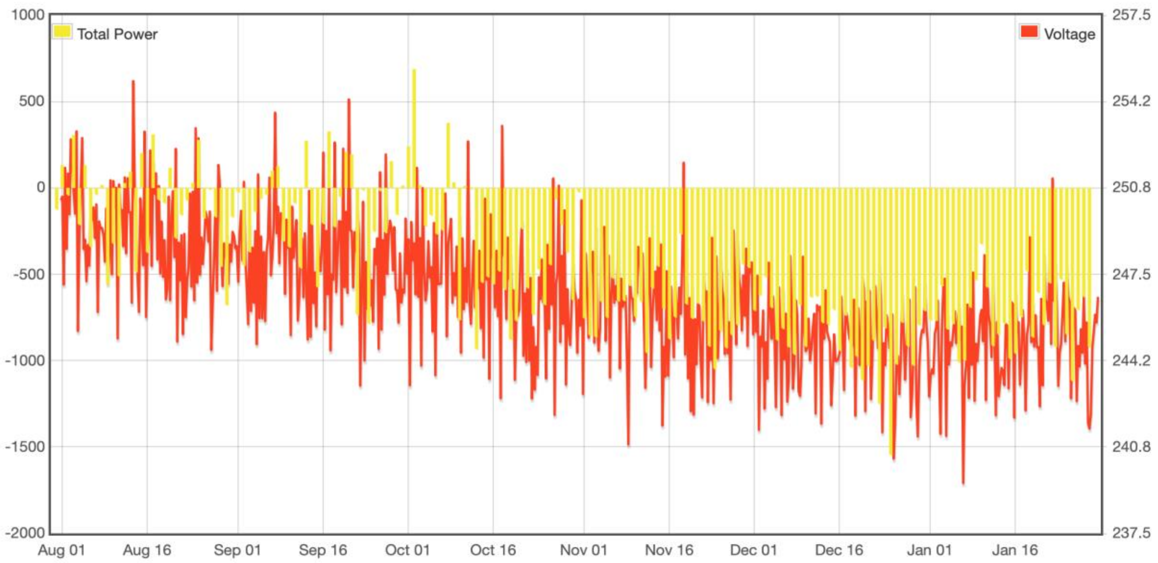
Findings

There are clear seasonal patterns evident in the daily energy consumption across most households. (Negative values denote export from PV installations.) This is as expected and will include a number of factors including seasonal variation of PV generators, increased requirement for lighting during the winter months and probably a certain amount of occasional heating by instant electric heaters.



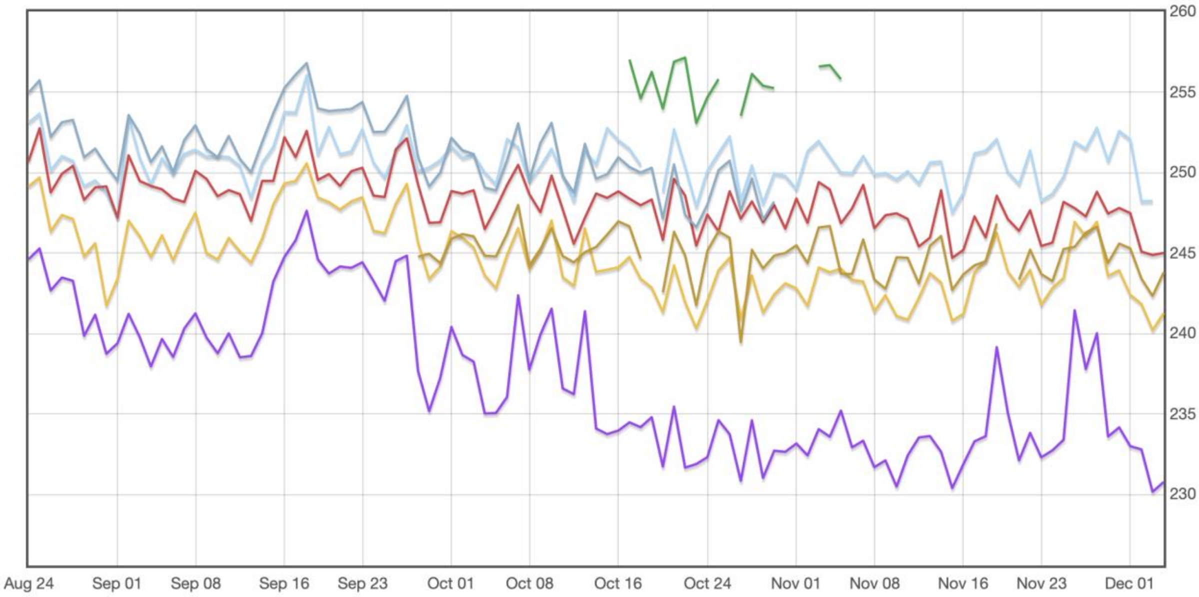
Daily power averages in Watts for each monitored household

It is also clear that the effects of line impedance cause measurable voltage drop when power is drawn. The voltage also rises when PV generation is exported onto the network. The following plot inverts the house power to better show the correlation between the average power and the average voltage at the dwelling. This effect can be seen at all levels of granularity and despite the unmeasurable impact of other nearby loads, measurements of the effective impedance of the line can be calculated for each monitored location.



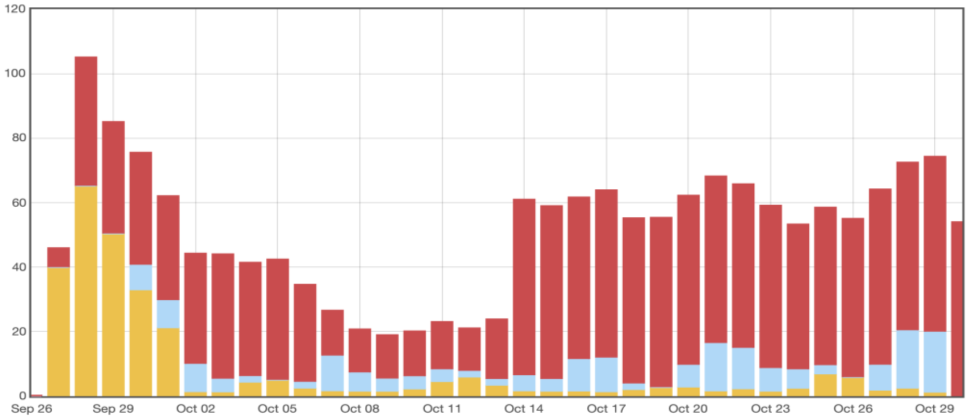
Average daily power and average daily voltage for one installation

Comparing the voltages at all sites reveals a similar pattern at each dwelling but with the voltages at some properties being consistently higher than others. It is worth noting that the connections for these premises are across both valleys and on transformers fed by different 11kV circuits. The statutory voltage limits on UK LV circuits is 230V +10%/-6%, ie, 216.2–253 Volts. The monitor units are not officially calibrated to a standard and may be misreporting the voltages but spot checks have not highlighted any glaring inconsistencies. Again, there is a clear reduction in terminal voltages as winter approaches and consumption increases.



Average daily voltage at each site during September–November

Some properties clearly exhibit dispatchable heating, generally connected to off-peak circuits and these are ideal for ANM participation. The consumption clearly varies between properties and according to other aspects, presumably weather and occupancy but the data demonstrates that tens of kilowatt-hours of dispatchable heating load are available, especially during the winter months.



Daily heating energy on separate circuits in three properties during October

FINANCIAL IMPLICATIONS FROM SURVEY AND MONITORING

A significant amount of money is spent by the residents of the CDC area each year on energy. Somewhere in excess of two million pounds (£2M) each year drains out of the valley to pay for fuels and electricity. The amount of energy consumed can be reduced by improving the efficiency of the equipment and assets involved and at least part of the expenditure could be retained within the area if generation can be enabled and links made to ensure that the generated electricity is consumed locally.

The extrapolated survey results show around £1m/year spent on electricity and heating, of which roughly 2GWh is electrical demand at present. We would estimate from our findings that 100MWh of this is flexible load at present, but that this could grow tenfold to 1GWh in the future, as heat and transport are electrified. Generation of 1GWh/year would lead to a gross income of around £50,000 if simply sold to the grid @5p/kWh, a typical wholesale rate in recent years. However, once local sale of electricity regulations are introduced, sales could be made locally for say 10p/kWh (mid-way between export values and typical domestic import values). This would potentially lead to a gross income of £100,000 for the community generator (greatly improving the generation business case relative to the current baseline), and a saving of £50,000 for local consumers compared to normal import prices.

1GWh of annual generation equates to an average production of just over 100kW, which could be achieved by a 1¼MW PV array or 300kW of wind or hydro generators. This level of community generation is reasonable and multiples of this could be achieved once transport and heat are significantly electrified in the valleys.

FACTOIDS

- Most households are two residents with single occupancy being the next most common
- The majority of dwellings have between five and eight rooms.
- Occupancy does not correlate strongly with size of dwelling.
- Ten dwellings have smart meters, all in the Ettrickbridge or Broadmeadows areas.
- 14 dwellings have Economy 7 meters but there are 11 electrically-heated homes without.
- Some homes with oil heating also have Economy 7 meters
- The main heating fuel is oil with gas, coal, electricity and wood also used.

- Most homes had retired residents (68%) and 44% had working members of the household. (12% had both.)
- Fewer than a quarter of homes were able to provide an EPC rating. These ranged from A to F with half being C or D. Three were better and five worse.
- Household renewables (on about a quarter or the dwellings) has an installed capacity of around 100kWp and an annual generation of over 50MWh.
- The 20kW hydro produces about 100MWhpa and the 200kW AD plant over 1GWhpa.
- The heat consumption is of the order of 1.6GWhpa although 20% of properties do not record a separated heat energy. The real total could be significantly greater.
- 22% of households switched supplier in the last year.
- One sixth of the properties have some form of storage, mainly in the form of storage heaters or hot water cylinders with electric immersion heaters. These represent about 100MWhpa of controllable consumption.
- There is already ½MW of dispatchable load feeding into storage in the valleys with potential to increase this to several MW of load.
- There is potential for 10MWh of energy storage in people's homes, not counting V2G.
- Over 10% of the surveyed households reported having two electricity meters but *not* being on an off-peak tariff. This may be historic but, given that the majority of these households have extant storage in the form of hot water cylinders with immersion heaters, there are likely opportunities for savings by switching to an off-peak tariff even where there is PV generation and a diverter.

SPEN GRID MONITORING DATA

SPEN installed four 'Gridkey' monitors on low-voltage transformers in the area (3 in Ettrickbridge and one in Yarrow). These gathered data from early December 2019 to early March 2020. Graphs for each of the locations showing the full 3 months, and sample weekly/daily power flows are available at Appendix 1. The data shows that during this period the transformers delivered peak power of up to 40kW per phase, and minimum loads of -4kW in some locations for brief periods (presumably where a particular phase exported back onto the distribution network as a result of embedded PV generation behind the transformer).

Only graphical data was supplied by SPEN, rather than the raw figures logged, so limited data analysis is possible, and the mean/median loads on these transformers remain unknown. However, in some cases trends can be identified; in Ettrickbridge, the weekly data does show a slight reduction over the weekend of the 29th Feb-1st March, as would be generally expected from grid data. The daily data also shows some interesting results; the Cross Keys and Woodend transformers show relatively low overnight loads, with peaks in the morning and early evening (as is also typical from grid data). At Yarrowford, there is also a large overnight demand visible, suggesting perhaps a relatively high uptake of night storage heaters behind this transformer, with scope for flexibility uptake. The Ettrickbridge transformer is perhaps the most unusual, with medium levels of overnight demand, and high demand from 0700-1500. The daily minimum occurs at 1600, with only a slight increase during the evening. As this transformer supplies the primary school, it is possible that this building accounts for the unusual profile, with higher demand for lighting and perhaps heating during school hours.

Given that it proved unworkable to collect live grid data on power flows into and out of the valleys from the main 11kV lines, the recommendation from SPEN was to simulate this aspect of the ANM demonstration. SPEN (and other DNOs) have experience of sending out grid data or curtailment signals/setpoints to generators from other ANM systems, so this aspect is already relatively well tried and tested. By simulating the grid data, the ANM controller could still have dispatched controllable loads as part of the demonstration, as well as sending simulated curtailment signals to the (at this stage theoretical) generator once loads became fully charged. SPEN were supportive of this demonstration being carried out, as these aspects are relatively novel and untested, especially at this scale and utilising affordable, off-the-shelf equipment.

During the course of the project, SPEN also noted that there was little capacity on the grid, and that creating more load rather than additional generation would be a more useful project outcome in their view. This is partly because a nearby anaerobic digestion plant has ended up exporting more onto the network than was originally anticipated. It is understandable that new flexible loads instead of additional generation would be a priority for SPEN as a DNO, as they have responsibility for balancing and ensuring the integrity of the local network. However, focusing solely on loads would not have helped EYCDC achieve the main project objective of improving the case for new community-owned generation in the area. It should also be noted that the observation of there being 'no capacity' for new generation was made prior to the analysis of household surveys or SPEN's own substation monitoring, and without any line monitoring data. It is likely therefore that this conclusion was based very much on a desktop analysis of potential capacity, as prior to the completion of the data collection and analysis work there will have been little to no robust data on power flows at different points in the valleys. Our overall conclusion is that there likely is scope to accommodate new generation whilst minimising (even reducing) reverse power flows back to Selkirk from both new and existing generation, if controls are fitted to new and existing loads in the valleys.

POTENTIAL FOR NEW GENERATION

Already within the valleys there is a 200kWe anaerobic digestion plant at Bowhill, and a small 20kW hydro scheme, plus limited amounts of roof-mounted PV on domestic properties. EYCDC has long wished to install new community-owned generation in the area, and previous feasibility studies have looked at PV, wind and hydro. Limited work has been carried out under this project to revisit these studies and refresh them to assess the scope and viability of such schemes in the present financial climate.

The most detailed study previously had been a 2015 wind assessment by Green Cat, looking specifically at sites on Helmburn Farm, near Ettrickbridge. This considered options for 1-2 turbines of 50-500kW in scale. The study found reasonable planning prospects, and expected windspeeds of around 7m/s, with some potential wind shear and turbulence. In most aspects, the scope for a wind development at this site was found to be low-medium risk, although grid capacity was flagged as higher risk, with the likely need for a dedicated 11kV line back to the Selkirk Primary for any connection over 50kW. The likely payback period for a 50kW machines was assessed as being 12-14 years (7-8 years for a 500kW turbine).

The main change since 2015 has been the end of the Feed-in Tariff, which will now make a wind development of 50-500kW very challenging financially. Furthermore, many small wind manufacturers (such as Endurance, recommended in the report, along with Harbon and Northern Power Systems) have become insolvent since the end of the FiT scheme, meaning it is now very difficult to find any turbines with a good track record at all below around 200kW. The challenging market conditions for this scale of turbine may make it difficult to secure bank finance even for the remaining manufacturers as banks may be concerned about their long-term viability and ability to provide spares and maintenance.

There is still reasonable availability of 'bankable' and well-proven 225-500kW turbines, but the initial feedback from EYCDC is that they would not wish to take forward a turbine development of that scale at Helmburn due to the visual impact, and a 50-100kW development would have been their preference. In any case, the likely voltage rise issues flagged by SPEN and the need for an expensive direct connection back to Selkirk mean that a 225-500kW turbine may well not be feasible on this site. We therefore conclude that there is **no immediate prospect for community wind generation in the area**, even if connected on an ANM basis.

In terms of hydro, the main previous work carried out had been a 2016 mapping study by Sgurr (now Wood) looking at potential sites within the area of operation of EYCDC. This was a purely desktop-based scoping study, without consideration of land ownership or obstacles visible on the ground.

The sites flagged up under this scoping study have not been assessed in detail under this project, nor on the ground. Some general observations can be made; again, voltage rise will be a constraint, particularly for larger sites and for those towards the western ends of the valleys (towards the end of the radial 11kV lines). Secondly, in most cases larger sites will tend to have greater economies of scale than small sites, and will generally therefore be more viable – however there is a tension between this and the first point on voltage rise. The most significant consideration, and a change since the 2016 study, is that without FiT income, it will be very difficult to make hydro sites of this scale viable in any location in the UK. We have not assessed the scope for direct local supply, which might improve the economic prospects, but there are no glaringly obvious opportunities for this nearby any of the shortlisted sites.

Prison Linns, the burn immediately west of Helmburn, had been flagged by EYCDC as a candidate site of particular interest, as the landowner would be receptive to a scheme here. The site had been excluded from the Sgurr assessment, possibly as the lower reaches form part of an SAC (although this isn't necessarily a show-stopper). A very cursory examination suggests that there is a potential catchment of around 6km^2, and a useable head of around 30m, with a pipeline of approximately 1km. Based on local river flow and catchment data, and an estimated flow of 28 litres per second per km^2 of catchment, an estimated 44kW of capacity might be available on this site. Even during the FiT period, this might have been marginal given the long pipe run, although might just have been economic if the penstock route could be optimised and microsited. At present, it would be highly unlikely to be viable; however, we can't see any reason this site shouldn't be on a shortlist in the future if the general economics of hydro change.

Overall however, given the voltage rise constraints, lack of FiT support, absence of apparent scope for large local loads for direct supply, and without legislation allowing for peer-to-peer supply of electricity, we would conclude that there is **no immediate prospect for community hydro in the area.**

PV was also assessed by Sgurr in a 2016 mapping exercise. Again, this was very much on a desktop basis, without consideration of constraints on the ground. Most of the potential sites identified were towards the central and western areas of the EYCDC operating area, and again would likely encounter voltage rise constraints at any significant scale.

Some specific roof- and ground-mounted PV opportunities have been identified at the Kirkhope Steading site, which EYCDC are planning to convert into a mixed business and housing development. PV costs have reduced to the point where they may be viable without additional support in some cases. There **may therefore be scope for community PV, including potentially larger 'solar meadow' developments,** if a grid connection can be secured; this is more likely towards the Yarrow and Ettrickbridge end of the valleys.

POTENTIAL MITIGATION TO VOLTAGE RISE

Voltage rise

The main constraint on the electricity network in the valleys is due to voltage rise. The circuits have been configured on the assumption of power flow from the 'primary' transformers in Selkirk to the 'secondary' transformers at settlements, farms and dwellings. When the power flows in the opposite direction due to 'embedded' generators on the distribution network, the voltage on the circuits close to the generator is higher than the voltage farther away. This dynamic could cause voltages on the HV circuits to rise above the maximum permitted voltage if such generators connected without other adjustments being made to accommodate this new power flow. All of the six hydro generators identified for analysis would cause a voltage rise higher than is allowed if no adjustments were made to the existing network configuration and parameters. Fortunately, due to the trials evaluated during the ARC project, there are solutions that could be implemented to prevent such problematic voltage rises from occurring.

'Standhill' Solution – transformer tap changer adjustment

The first, most thorough, solution is to set the starting voltage at the primary transformer to be slightly lower than usual. This allows more 'headroom' for the generator to feed into. The voltage rise still occurs but, because the starting voltage is lower than the unadjusted case, the final voltage is still within statutory limits. Careful analysis of the particular circuits and measurement of the voltages under operating conditions would need to happen to verify that this solution would be feasible.

'Ruchlaw' Solution – active voltage monitoring

The second solution is more pertinent to situations where the voltage rise problem is known to be intermittent but may also be appropriate for situations where the situation is dynamic and unpredictable. In this situation, a simple, closed-loop feedback system is established such that when the voltage at a particular pinch-point rises toward the upper limit, a signal is sent to the generator to reduce the power generated. Once conditions change and the voltage falls a safe distance below the limit, the generator can be signalled to increase its output again. Depending on the volatility of the situation and the sensitivity of the site, both the frequency and size of adjustments can be altered to allow a tight or lax control loop as appropriate. The disadvantage of this solution is that it does result in the curtailment of potential generation. The flip side of this is that a larger generator can be accommodated than would be possible under a fixed-output arrangement.

Power factor adjustment

When power flows into a resistive load, the current rises and falls in sync' with the voltage. This means that the voltage drop produced by the current flow adds directly to the voltage on the line;

it is “in phase”. If the load has a significant inductive or capacitive component (such as with a motor), the current will be out of phase with the voltage and the voltage drop will not add arithmetically to the line voltage. The same is true of generators and this dynamic can be used to allow greater current flows on the lines than would be permissible with the current in phase with the voltage. The relationship between the voltage and current is measured as a ‘power factor’ and it is possible for various types of generators to deliberately function at a non ‘unity’ (in phase) power factor. This mechanism can allow larger generators to connect in certain circumstances.

Automatic Voltage Regulators

AVRs are used on circuits that have voltage level problems and they allow significant voltage drops and rises to be compensated for by adjusting the voltage at a particular point on the circuit. They can be expensive pieces of equipment and can themselves introduce other limitations. DNOs are generally reticent to install AVRs in all but the most extreme of circumstances.

Thermal limits

Every conductor has a limit to the amount of current that can flow through it before it heats up beyond an acceptable level. Various problems can arise if currents are not controlled within safe parameters and these range from wire sagging farther than designed to the wires physically melting (fusing), causing the circuit to disconnect, often in a dangerous way. The network has been designed to safely carry the current necessary for all foreseeable situations but carrying the output from a generator was not within the design parameters of most segments of the network. Any generation added to the network that outputs more power than that consumed by the dwelling or other load that the circuit was designed to feed cannot be assumed to be able to be safely carried by the wires in that area.

The physical size of the conductors and the material that they are made of are the main factors that determine the current that can be safely carried by a section of network. Other factors have a measurable but less profound effect including ambient temperature and local air flow—both of which affect the cooling of the conductors. Ascertaining the installed gauge of each wire segment would provide a reasonable indication of the approximate limit to the current (and hence power) that can be transported by that wire.

Other limitations

Whereas voltage rise and thermal limits comprise the majority of constraints on the electricity distribution network, they are by no means the only constraints to contend with. Reverse flow capability of equipment, particularly transformers, can limit the amount of power fed back ‘up’ the system.

Fault Level refers to the current that can safely be handled by the circuit breakers and what currents can flow in the circuits under fault conditions. This can sometimes become an issue, especially on the higher voltage circuits. This is one constraint that is exacerbated rather than ameliorated by additional load close to a generator as both contribute to increasing the fault currents.

CONCLUSIONS & RECOMMENDATIONS

The principle aims of this project had been to investigate and demonstrate demand flexibility and ANM as a means to enable new community generation in the Ettrick and Yarrow Valleys. Ultimately, this has not been possible; this is in part due to market conditions for new renewable generation, rather than solely due to local grid barriers. There is no clear financial case at present for wind, and few if any models available in the 50-200kW scale preferred by EYCDC. Likewise, it is very difficult at present for any new hydro schemes to be economically viable. This might change somewhat once local sale of electricity becomes possible, but this mechanism is not currently available. Additionally, it appears that there are voltage rise constraints in the valleys, particularly further west and more distant from Selkirk Primary, which would not necessarily be alleviated through use of an ANM scheme. CES has identified some potential mitigation options for the voltage rise issue, but these would need to be investigated further with SPEN once a firmer site was identified for a potential hydro site. PV is more likely to be a viable option in some cases. The grid data secured by SPEN may be useful in the future in identifying particular transformers which PV could usefully be installed behind without causing upstream impacts on the network, or to indicate areas where there are likely to be flexible loads to match generation against.

The energy surveys and domestic monitoring revealed a significant amount, which would be valuable in a future ANM scheme or in other community-based projects to utilise local flexibility. From the 79 survey returns, with data scaled up appropriately to estimate the total domestic demand in the valleys, it was found that there is likely to be over 500kW of electrical storage heating already present in the area, with a storage capacity likely in excess of 1MWh (representing around 100MWh/year in controllable consumption). There is scope to increase this ten-fold as heating becomes electrified in the future.

In terms of existing generation in the area, taking into account local roof-mounted PV, the 20kW hydro and the 200kW AD plant, there is an installed capacity of around 320kW in the area, with an annual generation of over 1.15GWh. At present, this means that local generation does not exceed local electrical demand (which extrapolated from survey returns is probably around 2GWh/year at present), although there may well be times when the valleys are overall net exporters of power back to the Selkirk Primary.

Heat consumption in the area is estimated as being at least 1.6GWh/year, of which a relatively small proportion is from electricity at present. With over 60% of domestic energy coming from oil, LPG and coal, there is significant scope for electrification of heat, and indeed this is likely to become necessary on cost and climate grounds soon. This in turn means that flexibility is likely to become a necessity as well as an opportunity.

Likewise, just one of the 130 vehicles across the 79 surveys was electric, with the majority diesel; if the survey returns are representative of the valleys as a whole, then energy consumption for transport is in the region of several GWh/year at present, with around £1m/year spent on motor fuel. Again, as transport becomes electrified, there will be both an opportunity and a requirement for flexibility services around charging in order to manage network flows. The electric minibus procured as part of the project will present a great opportunity for demonstration and local trials in the area, to encourage uptake of EVs.

It is clear from the research carried out that there is a significant economic and environmental opportunity in the area to electrify heat and transport, and in so doing to create new flexible loads which could be matched against local generation, both new and existing. Somewhere in excess of £2M/year drains out of the valley to pay for fuels and electricity, and whilst efficiency upgrades should be the starting point, it is clear that there is significant scope to retain local income within the valleys through electrification and local supply. It is estimated that a 1.25MW solar array, or a 300kW hydro would be able to match against local demand, assuming they can be made to work economically, and that voltage rise constraints can be overcome, perhaps by the means outlined in the previous section of the report. If connected through a community-led ANM system (rather than one operated by SPEN as the DNO), it is anticipated that SPEN would wish to install an inter-trip (remotely-operated switchgear) at the generator to ensure SPEN could disconnect it if the ANM system fails to operate.

The ANM demonstration element of this project has not been progressed as the project has been curtailed by EYCDC, on the basis of the voltage constraints to new generation, and the limited value which EYCDC felt the demonstration would deliver with grid inputs and generation control both being simulated rather than live. However, with the data collected during the project, and the significant local education and dissemination work carried out, the Ettrick and Yarrow valleys will be in a much stronger position to pursue ANM and flexibility initiatives in the future.

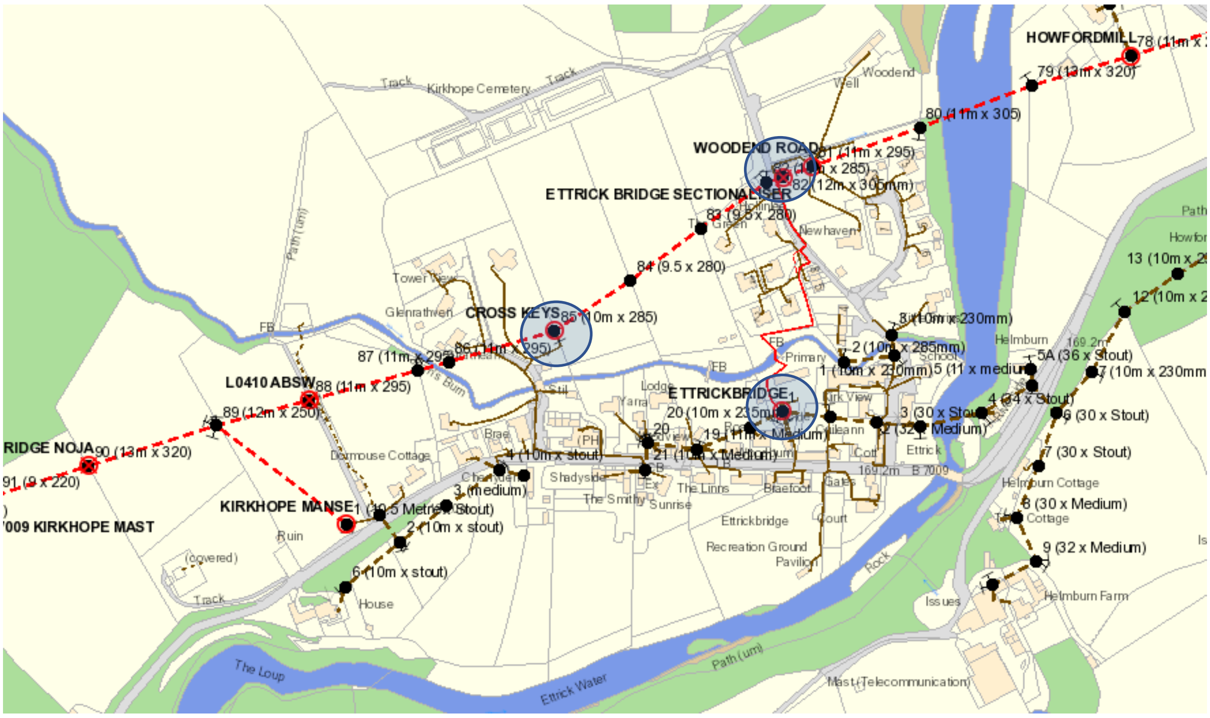
Recommendations

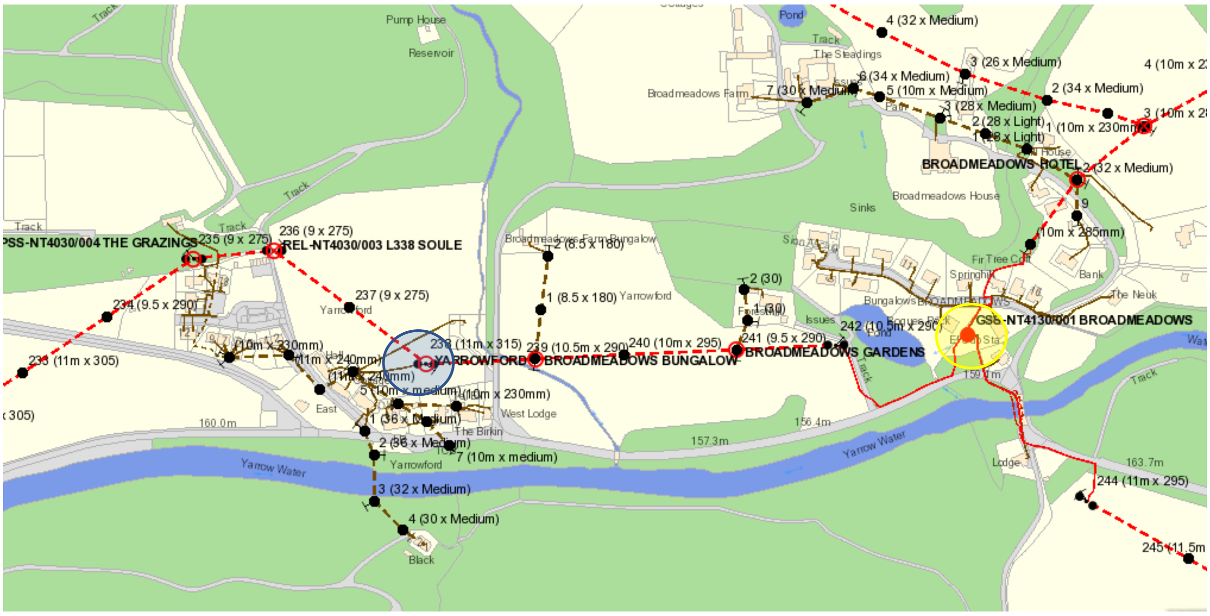
- Continue to use the EV minibus as widely as possible to showcase the opportunities available from EV use, and to allow local residents to experience driving an EV before investing in one.
- Install the EV chargepoints, ideally Type 2 socketed rather than tethered units, to allow for interoperability and use by residents and visitors to the area, as well as for the minibus.
- Consider establishment of an EV car club if there is sufficient interest in this locally.

- Disseminate the findings from the project widely in the area to spread word about the forthcoming opportunities from energy flexibility.
- Consider integrating flexibility elements into the Kirkhope Steading housing and business development, as well as the rooftop PV and shared ground loop heat pump system planned, in order for this to become a local demonstrator site for renewables and flexibility.
- Once local sale of energy becomes possible, discuss opportunities for local supply from the AD plant and micro-hydro scheme with their owners as a way of improving their export prices and reducing import costs for local consumers.
- Consider potential sites for small-medium PV generation in the area, particularly towards the eastern end of the valleys.

APPENDIX 1 – SPEN MONITORING DATA

Location of units

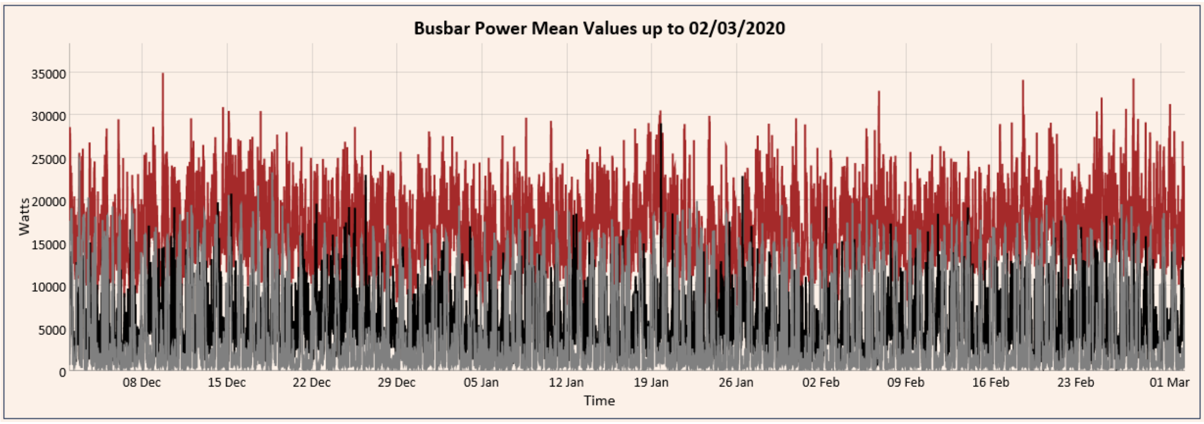




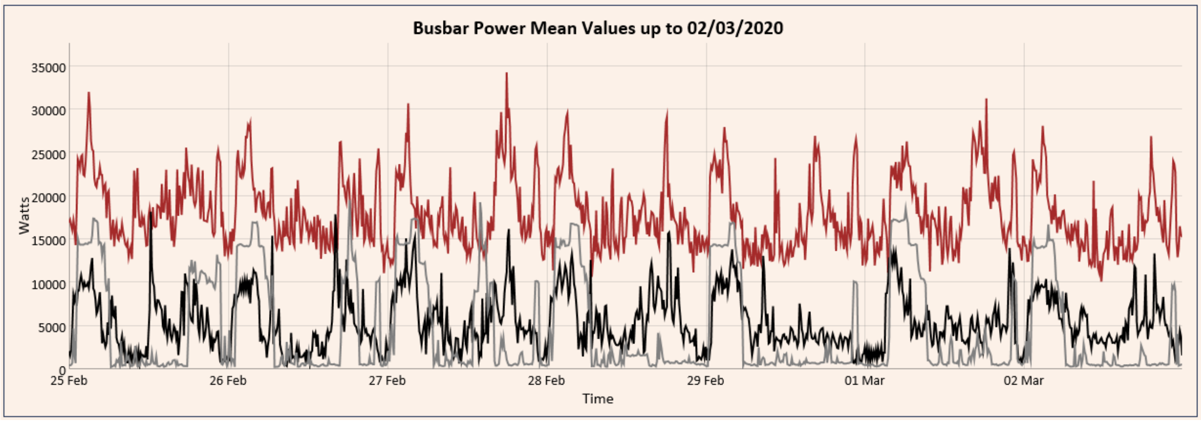
In the graphs below, it is presumed that the black, red and grey traces each represent one of the three phases supplied from the transformer.

Yarrowford

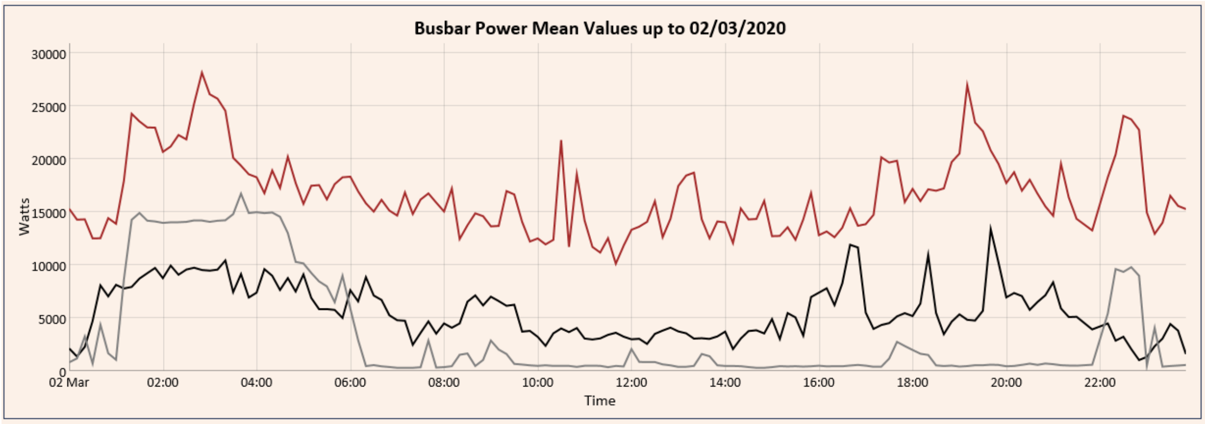
3 Month



Weekly

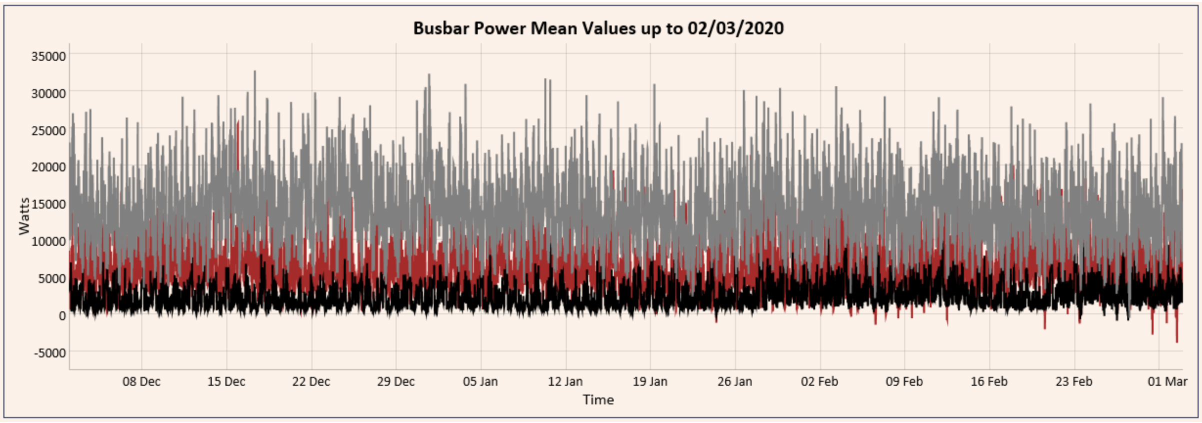


Daily

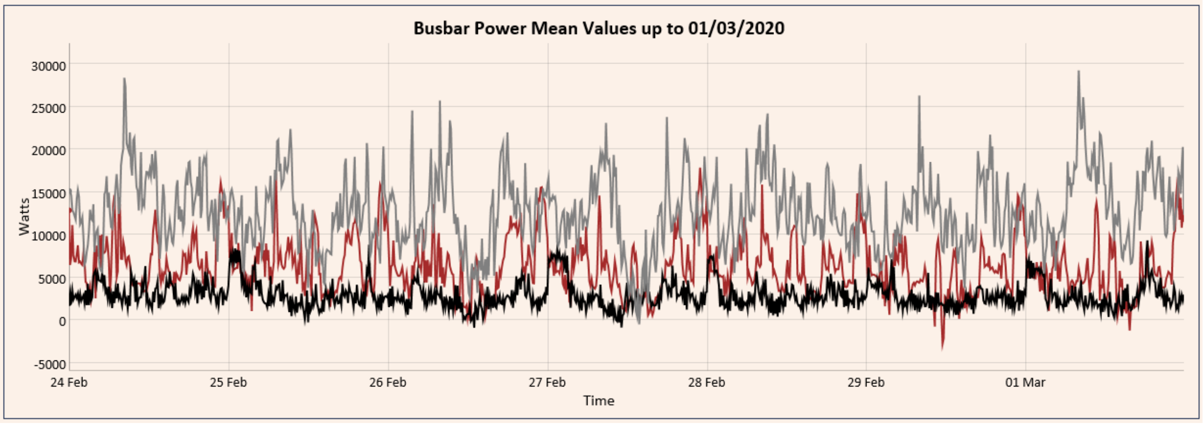


Woodend

3 Month



Weekly



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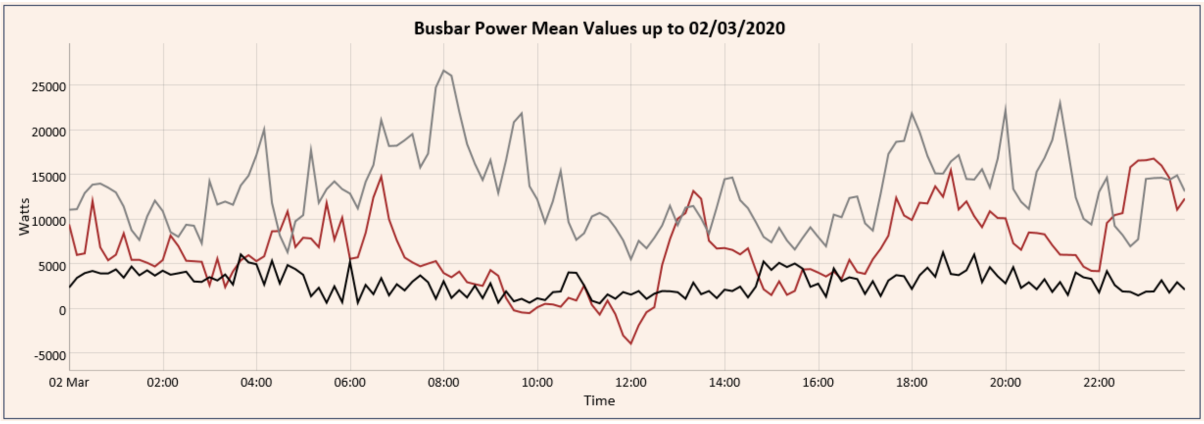
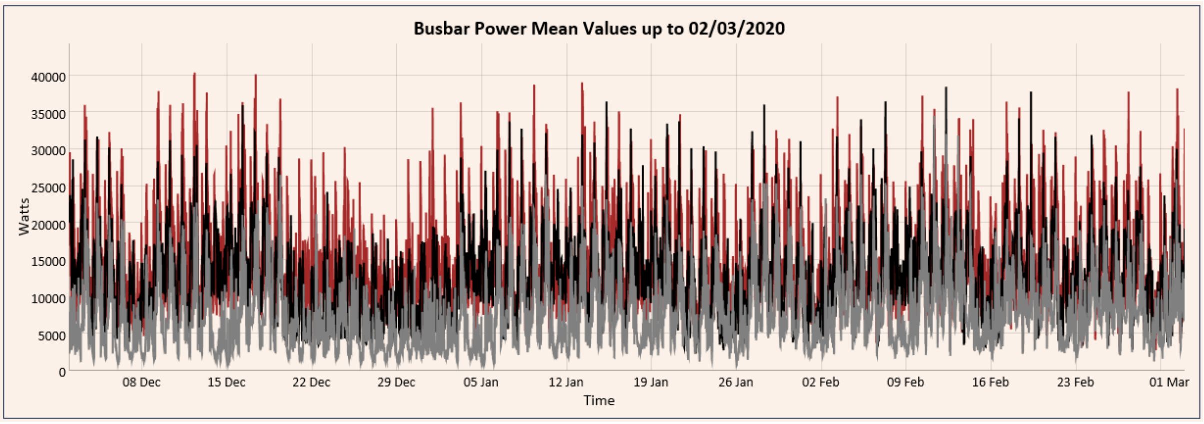


Ettrickbridge

3 Month



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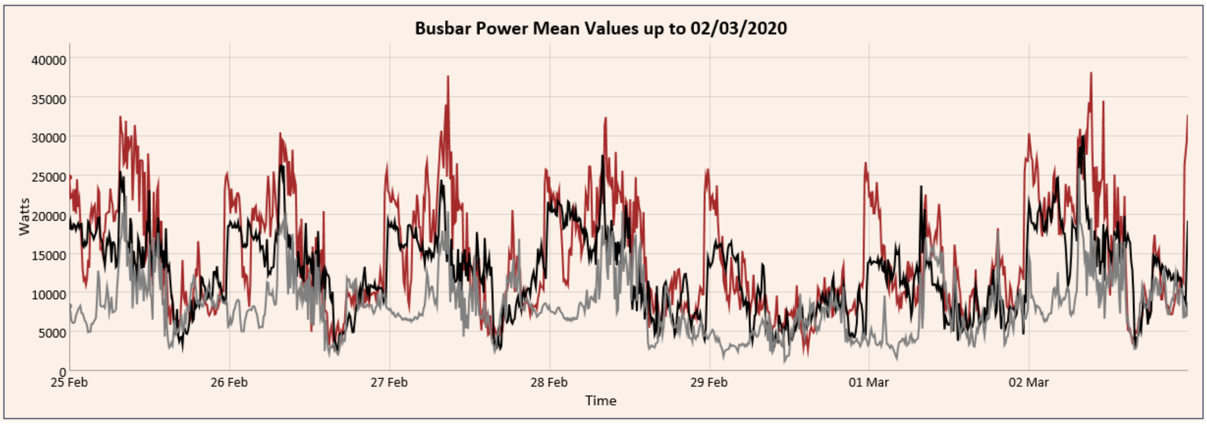

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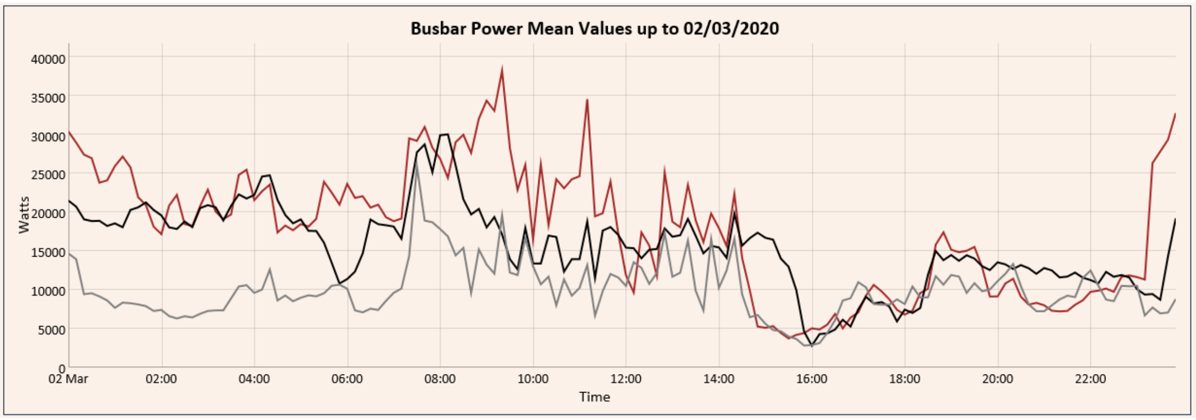
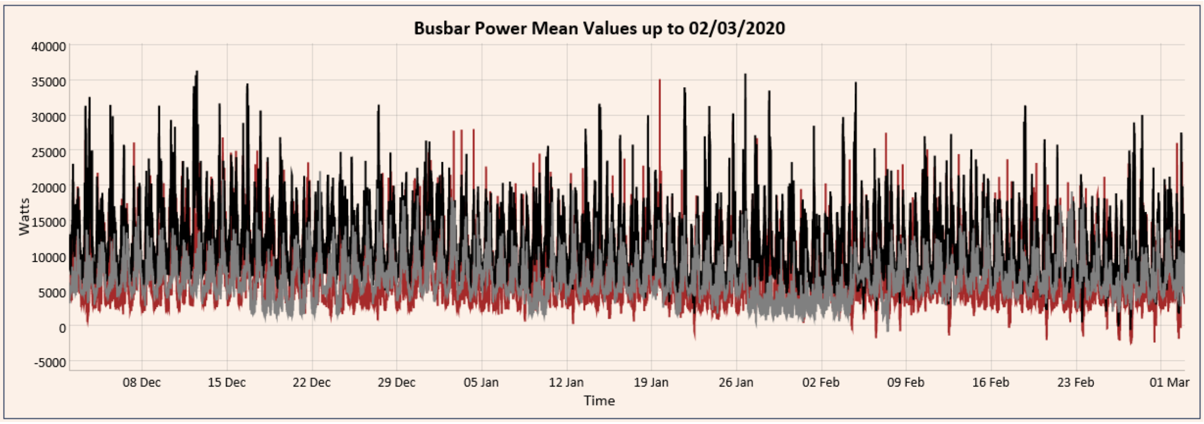


Cross Keys

3 Month:



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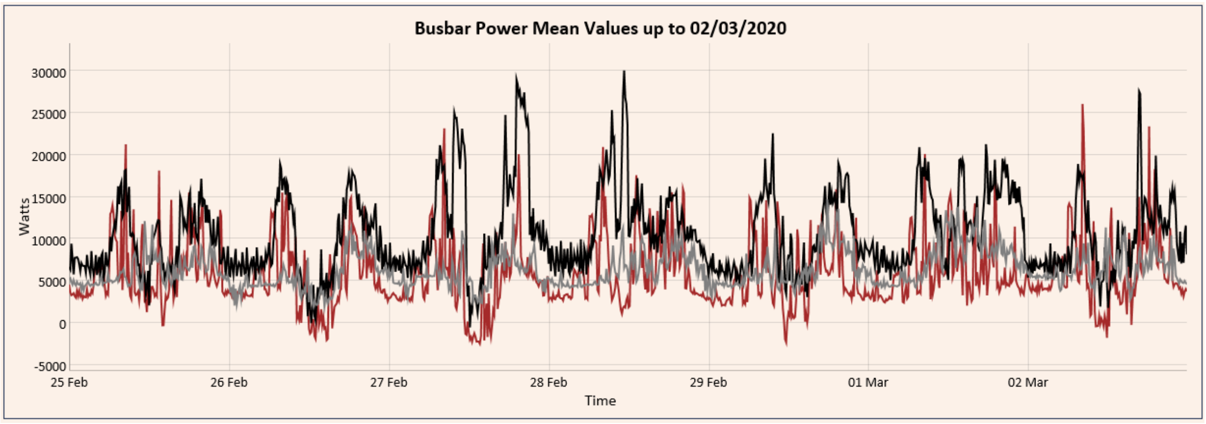

Daily: