Initial Load and Generation Profiles from CLNR Monitoring Trials

December 2012 SDRC Report

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Summary

The Customer-Led Network Revolution Project is undertaking a series of monitoring trials in order to understand current and emerging domestic, SME and industrial load and generation profiles within the UK. A *load* or *generation profile* is a common term to describe the diurnal pattern of load or generation for a given electricity customer or group of customers. Within a single day an individual profile will be highly unpredictable, but over time an average will emerge for a particular customer or customer group which demonstrates the likely value of the electrical load or export at a certain time of day. Values within load and generation profiles are typically recorded every half-hour, but may be more often; CLNR trials are studying both half-hour and 10-minute load profiles. Profiles are naturally seasonal and thus variation over the course of a single year, and between years, is of interest. CLNR is studying trials lasting 12-months in order to quantify a single years' worth of variation.

The CLNR trials are still on-going and this report represents a snapshot of the data that has been collected to date and provides some initial findings. Seasonal electrical load profiles for general customers, both residential and commercial (SME), are studied and presented. Data from a small group of customers with low-carbon technologies (heat pumps, electric vehicles, and solar PV) that are in the early stages of their trials have been examined, and some initial monthly profiles have been demonstrated. Lastly, an analysis of larger distributed generation sites has been undertaken with a view to understanding the ill-defined concept of a "generation profile"; various classes of generation from a large dataset have been identified and presented from the data.

While load and generation profiles are of interest in themselves, there is also a specific requirement within the CLNR project to recommend updates to electricity industry standards ACE49, ETR130 and P2/6, which define how load and generation types are to be considered in distribution network design. The profiles demonstrated herein are a first-stage preparatory exercise to understand and classify the CLNR data collected during the trials, and to identify further analysis that is required to allow these recommendations to changes to industry standards to take place. Development of the theoretical and computational methods required to incorporate new load profiles into the load and generation standards is on-going within the CLNR project, and will be informed by the output of this analysis.

This report is accompanied by a series of datasets in Excel spreadsheet form which contain the derived load profiles and additional explanatory data. These datasets are provided in an open and usable format for use by other distributors and researchers. Appendix B – Datasets describes the files provided and their contents.

Glossary of Terms

CLNR	Customer-Led Network Revolution
SDRC	Successful Delivery Reward Criteria
LO	Learning Outcome
TC	Test Cell
SME	Small or Medium-sized Enterprise
I&C	Industrial and Commercial
PV	Photovoltaic (solar panels)
EV	Electric Vehicle
HP	Heat Pump
Micro-CHP	Micro Combined Heat and Power (generator)
Cogen	Cogeneration (large-scale CHP)
DSR	Demand-Side Response
ETR 130	Engineering Technical Report 130 - Application Guide For Assessing The Capacity Of Networks Containing Distributed Generation
ACE 49	Report on Statistical Method for Calculating Demands and Voltage Regulations on LV Radial Distribution Systems.
P2/6	Engineering Recommendation P2/6 – Security of Supply
LCT	Low-Carbon Technology
DG	Distributed Generation
Weekday	Monday-Friday
Weekend	Saturday and Sunday

Project Partner Abbreviations

BGB	British Gas Business
BGR	British Gas Residential
DEI	Durham Energy Institute
NPG	Northern Powergrid

1 Introduction

This report describes a series of CLNR Monitoring Trial summary data produced to meet the requirements of the CLNR Project December 2012 Successful Delivery Reward Criteria (SDRC) Milestone, which is defined as follows:

> *Provision of the following data sets for availability and use by other distributors and researchers:*
>
> - *Demand profiles grouped by customer type by end 2012;*
> - *Demand profiles grouped by low-carbon technology type by end 2012;*
> - *Demand profiles of existing generation types by end 2012.*
>
> *Evidence: data sets in an open and useable format issued to distributors and other interested parties.*

Learning Outcome 1 of the CLNR project defines a set of eight monitoring trials which measure domestic and business electricity use over an annual cycle. Each trial is labelled as a *test cell* and defines a combination of customer grouping; metering type, and new electrical load; the study of each being intended to answer questions about current, emerging and future customer load and generation characteristics. The Customer-Led Network Revolution Full Submission Pro-Forma (Optional Appendices – Appendix 4)[1] explains this in more depth. The test cells studied in this report are the following:

- Test Cell 1: *Basic Profiling of Regular Smart Meter Customers*. This test cell is further divided into TC1a (Domestic) and TC1b (Small Commercial) groupings.
- Test Cell 3: *Enhanced Profiling of Heat Pumps on Flat-Rate tariff.*
- Test Cell 5: *Enhanced Profiling of Photovoltaics.*
- Test Cell 6: *Enhanced Profiling of Electric Vehicles on Flat-Rate tariff.*
- Test Cell 8: *Profile for Generation under Smart Tariffs*

Data relating to Test Cell 7: Understanding impact of April 2010 tariff reform are not included as part of this report, as these were analysed to study the effect of the introduction of the Common Distribution Charging Methodology. We will investigate load profiles for these customers in due course also.

Customers in the LO1 test cells are largely unaware of the effect of their load and generation on the network, and are not involved in a novel commercial proposition (e.g. time-of-use tariff, DSR scheme, etc.). A more comprehensive description of LO1 and the monitoring schemes being conducted can be found in the CLNR Ofgem Submission Optional Appendices – Appendix 4.

The data collected from these customers are intended to baseline the general load case as well as examine new electrical load and generation types. Load and

[1] http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=98&refer=Networks/ElecDist/lcnf/stlcnp/year1/customer-led-network-revolution

generation profiles will be used in studies of the effect of the introduction of new commercial propositions, and also factored into network studies involving voltage control, energy storage, line thermal ratings, and demand response. The profile data will also factor into recommendations to update ACE49, ETR 130 and P2/6, and will be used to inform future load profiles based on projections of possible load mixes to 2050 (e.g. DECC's 2050 Pathways Analysis[2]).

Trial participant recruitment, and subsequent metering installation, has taken place during 2011 and 2012, and the first set of data to be collected is explained and presented in this report. Further information about the customer selection and recruitment processes will be released by the project in additional future reports.

The remainder of this report is dedicated to a per-test cell summary of the data collected by the project to date. This will include discussion of the data itself (source, size, processing), the analysis methods and tools used, and finally the results. A series of spreadsheets accompanying this report contains the derived data and results of analysis, and all charts and graphs demonstrated herein are reproducible using this data.

[2] http://www.decc.gov.uk/en/content/cms/tackling/2050/2050.aspx

2 LO1 Monitoring Trials

2.1 Data Summary

Table 1 shows summary information for the LO1 monitoring trials analysed in this report. The details therein will be explained and expanded upon in the following sections, which deal with each test cell in turn. Note that no data for Test Cell 4 (micro-CHP) or Test Cell 2 (disaggregated household load study) are available at this time.

LO1 Monitoring Trials								
TC	Description	Data Supplier	Data Type	Units	Trial Start	Trial End	No. studied to date	Total in trial[3]
1a	General Load - Domestic	BGR	30-min average	kWh	01/05/2011	31/05/2012	5554	8909
1b	General Load - SME[4]	BGB	30-min average	kWh	01/09/2011	30/04/2012	1795	2240
3	Domestic Heat Pumps	BGR	10-min average	W	05/07/2012	31/09/2012	2 to 23	322
5	Domestic Solar PV	BGR	10-min average	W	01/05/2012	31/09/2012	88	150
6	Domestic Electric Vehicles	BGR	10-min average	W	11/05/2012	31/09/2012	1 to 2	150
8	Distributed Generation (G59 Connections)	NPG	30-min average	MW	01/03/2009	20/04/2011	160	230

Table 1 – LO1 Monitoring Trials Overview

[3] This is the expected total number of participants that will be monitored once test cell start-up is completed.
[4] Data for May-Aug 2011 was collected but was discarded because of metering errors. It is expected that an updated analysis will be produced in future with 12 months of SME data.

2.2 Test Cell 1a Domestic General Load

2.2.1 Overview

Test Cell 1a participants are recruited from British Gas domestic smart meter customers. No interventions such as time of use tariffs or load control are present for these customers. 8909 participants are recruited to this test cell. At the time of analysis, data was available for 5872; and of these, 5554 were selected for analysis based on their having a complete 12 months of data. All meter data is half-hourly average electrical energy consumption in kWh for the period 01/05/2011 to 31/05/2012. Data within this sample includes customers from in and out of the Northern Powergrid region in an approximately 50/50 split; this is in order to aid applicability of the test cell results to other regions.

Test Cell 1a was analysed as a whole, and also by developed environment type (i.e. Urban, Suburban, Rural On-Gas and Rural Off-Gas. The type of developed environment was identified during trial design as a factor affecting electricity consumption and is a clear candidate for a first-pass partition of the trial. Further partitioning classes will be considered in future analysis. Table 2 shows the numbers of trial participants in each developed environment class in this analysis.

The results of the analysis for Test Cell 1a are presented in this report for participants in the Urban developed environment grouping. The same analysis has been performed on participants in the remaining groupings. These results are presented in the datasets which accompany this report.

Inter-sector comparison for domestic customers is not presented in this report. This work will be presented in future combining both quantitative and qualitative results from technical and social analysis.

It is important to note that English bank holidays have been removed from the datasets.

Developed Environment	**Allocation total**		**No. of files in dataset**		**No. of files with 12 months data**	
Rural Off-Gas	72	0.8%	20	0.3%	17	0.3%
Rural On-Gas	1116	12.5%	693	11.8%	652	11.7%
Suburban	2241	25.2%	1351	23%	1260	22.7%
Urban	5480	61.5%	3808	64.9%	3625	65.3%
Total	**8909**	**100%**	**5872**	**100%**	**5554**	**100%**

Table 2 – Breakdown of Datasets for TC1a Analysis

2.2.2 Analysis – Monthly Average Profiles

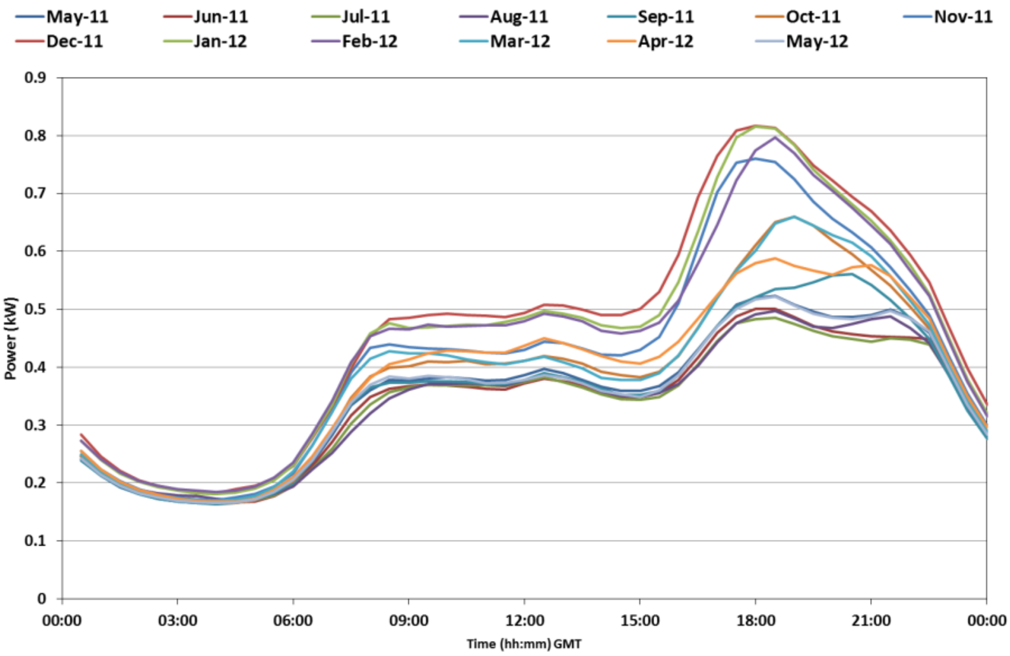

Figure 1 – Average monthly power consumption per half hour for all Urban customers

Figure 1 shows the average monthly power consumption for urban customers in the TC1a sample. The maximum and minimum demands for individual half hours across the sample have been found to shift between months; however this is limited to specific months.

Maximum demands were recorded in the December 2011 to February 2012 period with minimum demands seen in the May 2011 to September 2011 period. Whilst the greatest number of half hours with maximum demand was seen in December 2011, a significant percentage of half hourly maximums were recorded in February 2012. The results of this analysis are shown in Table 3.

Month	Percentage of Maximum Demand values (%)	Percentage of Minimum Demand values (%)
May_11	0	8.3
June_11	0	18.8
July_11	0	37.5
August_11	0	18.8
September_11	0	16.7

Month	Percentage of Maximum Demand values (%)	Percentage of Minimum Demand values (%)
October_11	0	0
November_11	0	0
December_11	81.2	0
January_12	2.1	0
February_12	16.7	0
March_12	0	0
April_12	0	0
May_12	0	0

Table 3 – Percentage of half hourly maximum and minimum demands per month – Urban customers

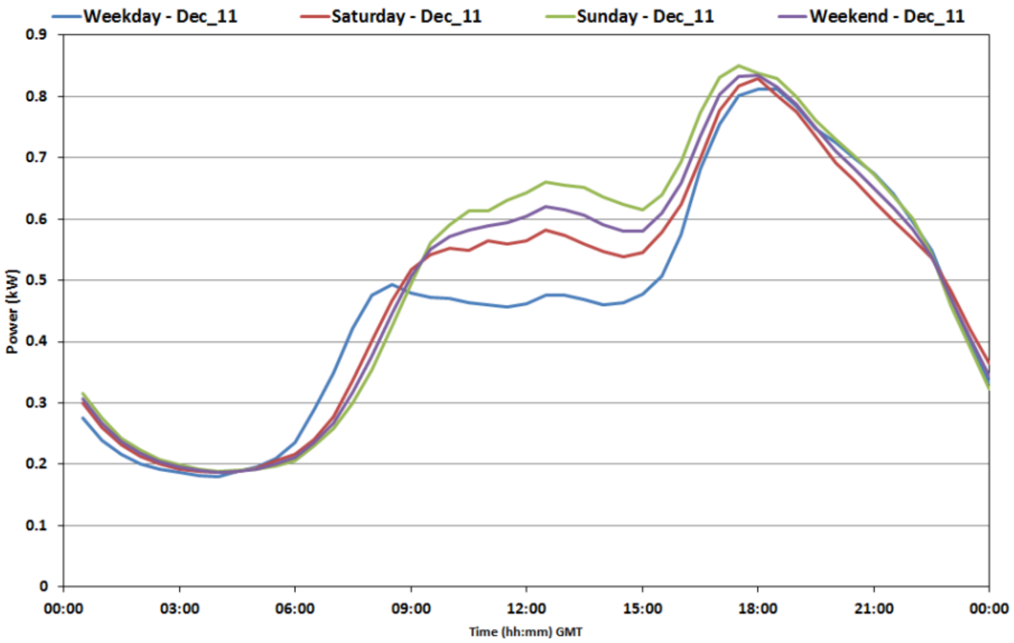

Figure 2 – Average weekday, weekend, Saturday and Sunday power consumption per half hour December 2011 for Urban customers

It is assumed that domestic consumption can be correlated strongly against occupancy patterns and so an assessment of intra-week variations was undertaken. Figure 2 shows average weekday, weekend, Saturday and Sunday profiles for the month of December 2011. Similar results have been observed for all months in the sample. Weekday consumption has a significant peak at around 08:00 which is not observed in the weekend profiles; the principal hypothesis for the absence of this peak at this time is there being a reduction in early morning commuting, therefore reduced overall domestic activity and lighting load. The maximum recorded demand on average occurs in the Sunday evening period.

Figure 3 shows the average weekday demand for all urban customers on a half hourly basis. Figure 4 shows the same analysis for weekend consumption.

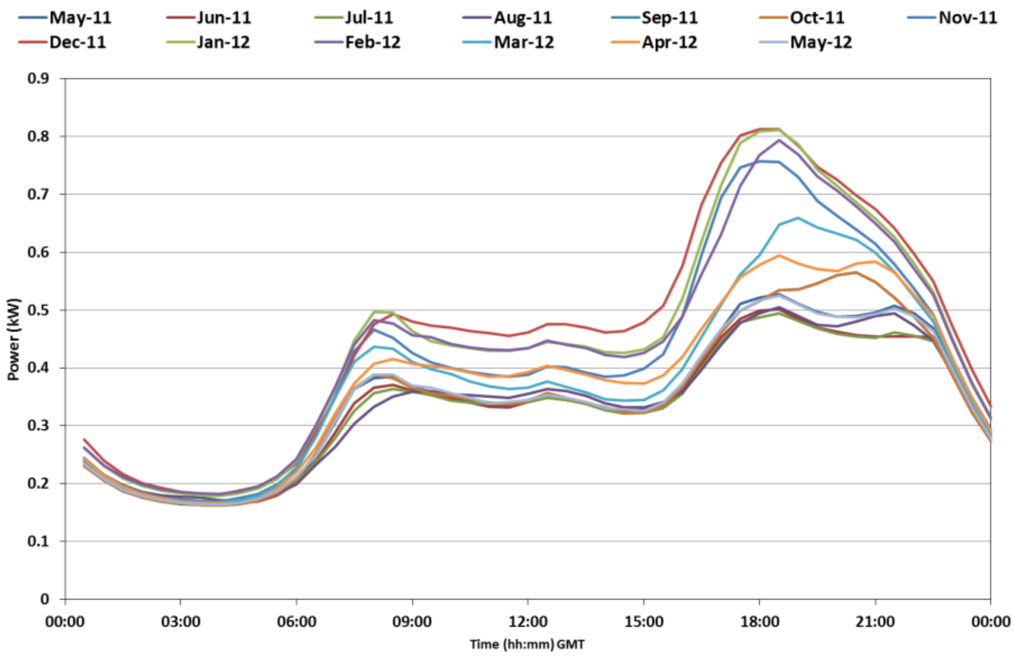

Figure 3 – Average monthly weekday power consumption per half hour for all Urban customers

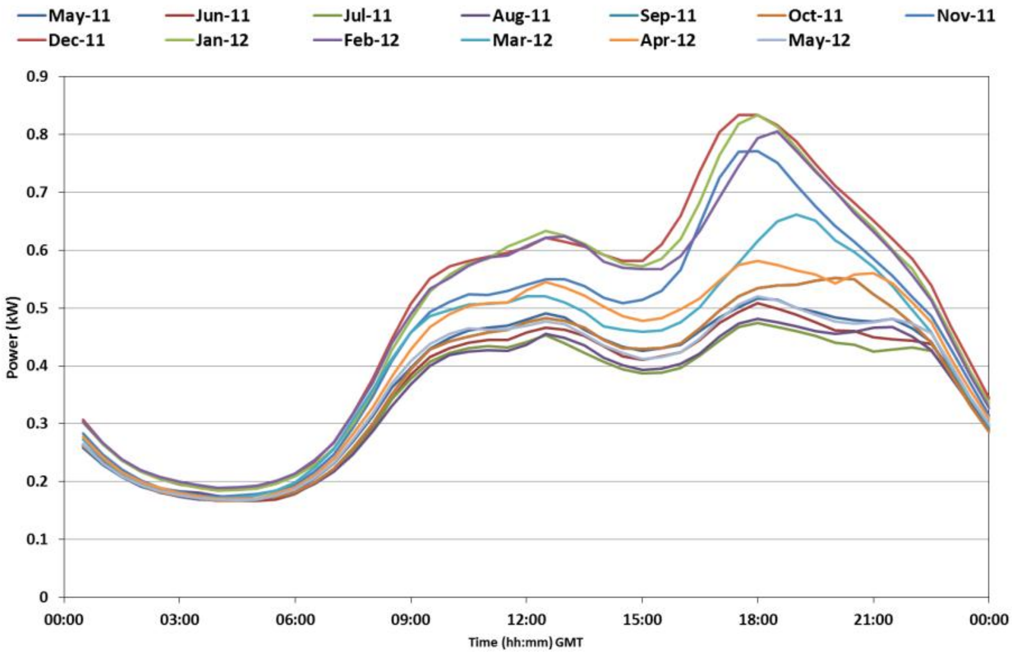

Figure 4 – Average monthly weekend power consumption per half hour for all Urban customers

Figure 5 shows 5th, 50th and 95th percentile values for the load of urban customers for the 19th and 20th of December 2011. These days have been chosen based on knowledge of network-wide peak demand occurring on these days. The average demand across the sample for these two days is also shown.

Each series represents the relative percentile of demand for an individual half hour, for this singular group of customers. I.e. a value taken from the 95th percentile series indicates that 95% of the demand for the entire sample is less than that value at that given point in time.

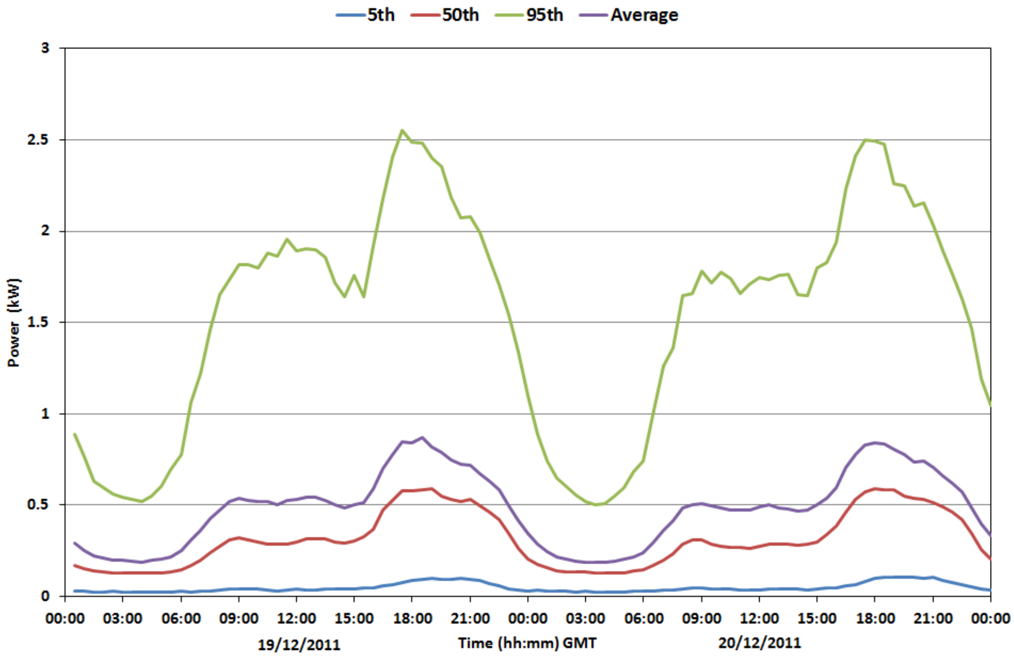

Figure 5 – 5th, 50th and 95th percentile limits with sample average for Urban customers

In order to quantify variation in weekday consumption, and weekday consumption against weekday the per-unit (p.u.) system has been used i.e.

$$\frac{Average\ Monday\ (November\ 2011)}{Average\ Weekday\ (November\ 2011)} = Load\ (p.u.) \qquad \textbf{(1)}$$

Figure 6 shows the results of this analysis. A value of 1 p.u. would indicate perfect correlation between days of the week and the average weekday profile. The results are presented in the form of box and whisker plots, with one plot per week day. The blue box represents the inter-quartile range, i.e. from the 25th to the 75th percentile. The red line within the blue box represents the average value for the particular day. The lines extending from the box (or whiskers) show the location of the furthest outlier from the dataset provided that it is in the following range

- Smaller than the 75th percentile + 1.5 x (75th percentile – 25th percentile)
- Larger than 25th percentile – 1.5 x (75th percentile – 25th percentile)

If values do not lie within this range, they are shown as red crosses. The smaller the box, the smaller the spread of values for that particular day. Monday and Friday show the largest inter-quartile ranges and the largest range of outliers in the Monday-Friday period, with Tuesday, Wednesday and Thursday showing smaller deviation away from the average weekday profile. Saturday and Sunday display a large inter-quartile range with significant deviation away from the average weekday profile, as expected. No outliers are plotted for the Saturday and Sunday profiles since the inter-quartile range is large in comparison to the Monday-Friday period.

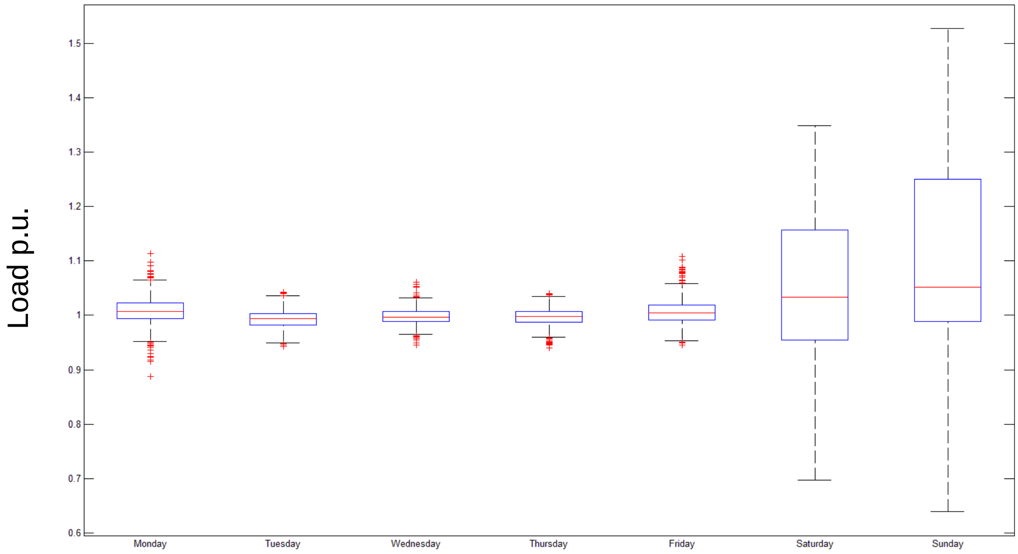

Figure 6 – Variation between weekday and weekend profiles, referenced to the average weekday profile

The findings from this analysis show that Monday, Friday, Saturday and Sunday are the days with greatest variations away from a typical weekday and have therefore been analysed in greater detail. Figure 7 shows monthly Monday p.u. load values for each half hour.

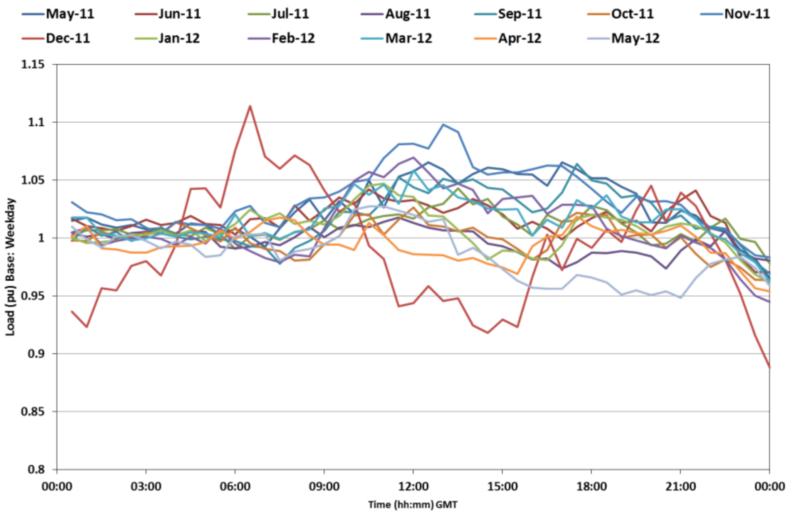

Figure 7 – Per-unit load values for Monday/Weekday for all months in the sample

Figure 7 shows that consumption for most months is greater in comparison to the average weekday after 09:00, with a significant number of values above 1p.u. Due to the removal of bank holidays from the dataset, results for December_11 will be subject to more uncertainty as after removal fewer Mondays remain in comparison to other months.

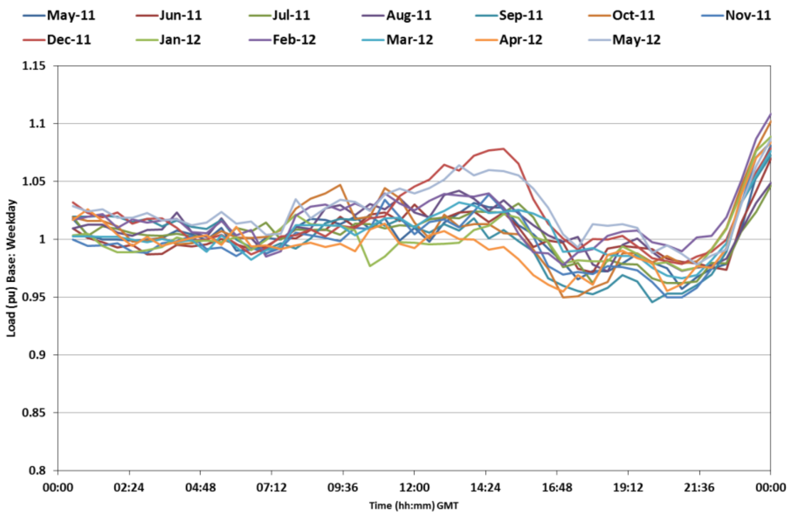

Figure 8 - Per-unit load values for Friday/Weekday for all months in the sample

Figure 8 shows the same analysis as before for Friday as a p.u. value of load. Greater than average consumption after around 09:00 is followed by a period of load reduction from around 17:00. This is followed be a homogenous significant load increase against average weekday from roughly 22:00.

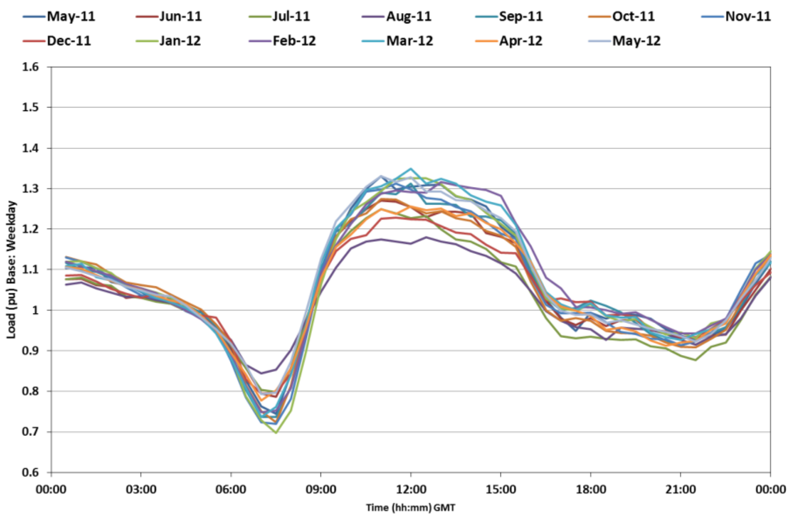

Figure 9 – Saturday p.u. values (referenced to weekday)

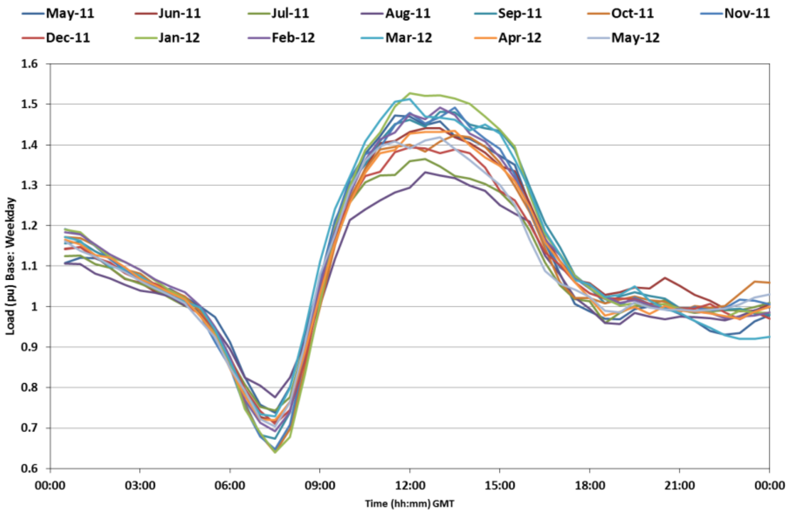

Figure 10 – Sunday p.u. values (referenced to weekday)

Figure 9 and Figure 10 show Saturday and Sunday p.u. values respectively. The days follow a similar load shape, with a higher peak demand observed on Sunday afternoons. Demand is increased in the early morning, followed by a significant reduction in demand between 06:00 and 09:00. The likely reasons behind this load reduction have been discussed previously. A large increase against weekday between 09:00 and 18:00 can be most likely attributed to a greater probability of consumer occupation at this time. Similar demands are seen in the post 18:00 period for Sundays, however as for Friday an increase in demand is observed for Saturday profiles, again from around 22:00.

2.3 Test Cell 1b SME General Load

2.3.1 Overview

The dataset for Test Cell 1b contains half-hourly metered electricity consumption data for British Gas Business customers categorised as Small and Medium-Sized Enterprises (SMEs).

Test Cell 1b was analysed by broad sector classification (SIC code) and, further, by tariff type (flat or multi-rate). Sector classification and tariff type were identified during trial design as a factor affecting electricity consumption in SMEs[5] and are clear candidates for a first-pass partition of the trial. Further partitioning classes will be considered in future analysis. Table 4 shows the numbers of trial participants in each developed environment class in this analysis; the actual numbers recruited to the trial are comparable with the designed numbers, and the proportions analysed to date are in line with the proportions in the whole sample, i.e. the sample analysed is broadly representative of the sample proportions.

Sector and Tariff		No. in Trial Design	Total no. of actual trial participants		No. of participants analysed to date	
Agriculture / Hunting / Forestry / Fishing	Flat-rate	180	144	6.4%	129	7.2%
	Multi-rate	78	45	2.0%	38	2.1%
Industry	Flat-rate	360	368	16.4%	301	16.8%
	Multi-rate	156	130	5.8%	89	5.0%
Office / Commercial	Flat-rate	520	563	25.1%	461	26.7%
	Multi-rate	226	247	11.0%	163	9.1%
Public Sector / Other	Flat-rate	515	537	24.0%	484	27.0%
	Multi-rate	221	206	9.2%	130	7.2%
Total		**2256**	**2240**	**100%**	**1795**	**100%**

Table 4 – Numbers of TC1b Trial Participants

Average monthly profiles have been derived for all participants in each sector with further sub-classifications of flat rate and multi rate sites. In addition to monthly profiles, weekday and weekend profiles have also been calculated. The following

[5] Project test cell design documents release pending

sections present these load profiles. Information on the composition of business in each SME sector can be found in Appendix A – TC1b Aggregated SME Categories[6].

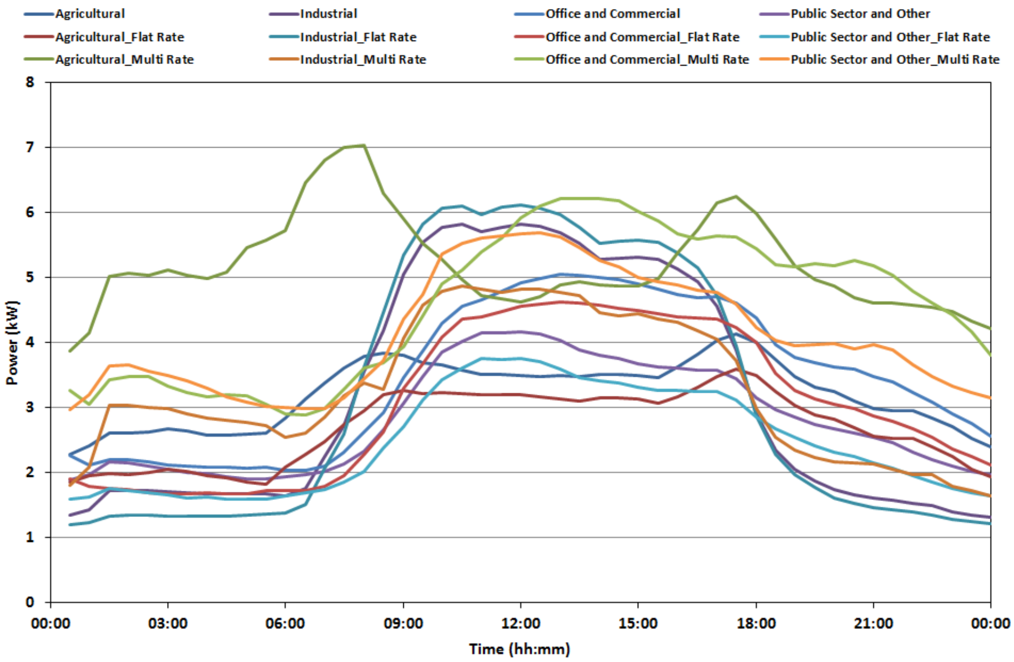

Figure 11 – Average weekday profiles for December 2011 – All SME sectors

[6] Note that at the time of analysis only the aggregated categories are available for each customer, not the specific SIC code. The aggregated categories reflect the broad categorisation affecting energy use and were used to select participants for the trial, to give a broadly representative spread of industries. Future analysis will consider the more detailed individual SIC code.

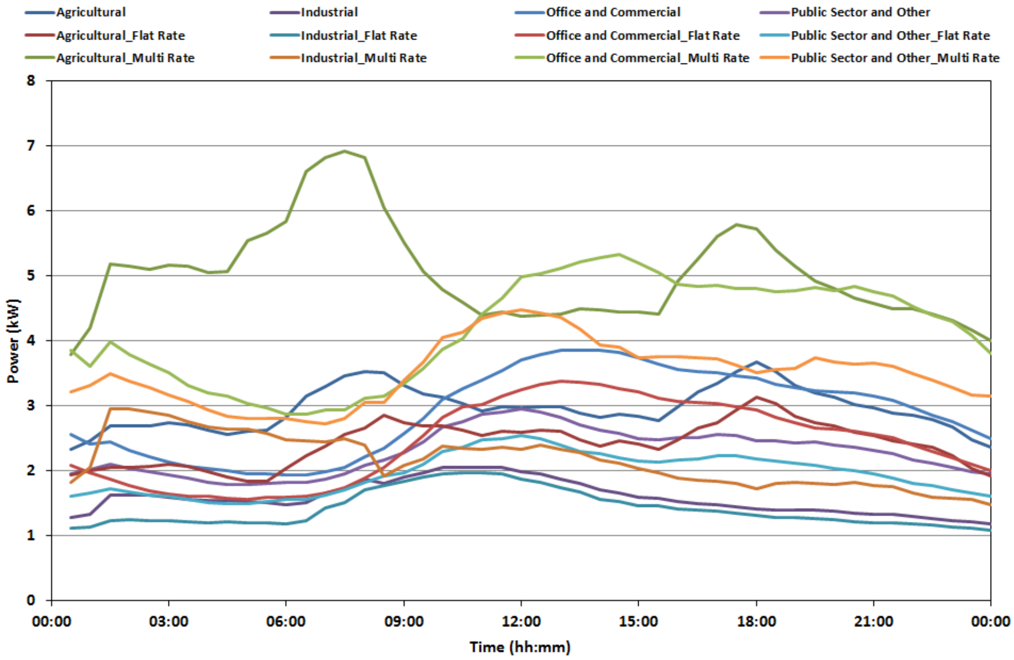

Figure 12 – Average weekend profiles for December 2011 – All SME sectors

Figure 11 and Figure 12 show average weekday and weekend profiles for SME participants per sector for the month of December 2011. Results for all months in the sample have been derived and can be found in the datasets linked to this report. Each sector will be discussed individually in the following sections. Preliminary analysis however shows a significant difference between weekday and weekend profiles in the industrial sector and distinct similarity between weekday and weekend profiles in the agricultural sector. Multi-rate participants also show higher early morning consumption than those on a flat-rate tariff. This is in line with increased early morning demand for domestic customers with electrical storage heating.

2.3.2 Agricultural

A twin-peaked load profile is apparent for both the weekday and weekend profiles for multi-rate and aggregate sector participants, with significant similarity between the two profiles. The early morning peak (01:30) is most prominent for the multi-rate tariff participants within this sector.

A significant peak in demand is seen at 08:00 and 07:30 in the weekday and weekend profiles respectively for the multi-rate sample. This peak is larger than the second peak in demand which occurs at around 18:00.

The flat-rate profile does not display such a definite twin-peaked load profile; therefore it is likely that the aggregate sector profile is dominated by the multi-rate participants. It can be concluded that the separate study of flat-rate and multi-rate profiles is therefore of importance.

2.3.3 Industrial

Clear dissimilarities exist between the weekend and weekday profiles for all tariff types in this sector, indicating a significant but not uniquely Monday-Friday operational period for the sites in this sample.

For weekday profiles within the sector, multi-rate participants show the distinctive early morning demand which has been previously discussed. A peak at 01:30 is followed by a reduction in demand to roughly 06:00, whereupon the demand increases to around 6kW. After this peak the demand follows a similar pattern to that shown in the flat rate sample. The peak demand for multi-rate participants in this period is lower than for the flat-rate participants. Two distinct 'notches' are present in the flat-rate profile occurring at 11:00 and 14:00 respectively. These notches are not found in the multi-rate profile. Demand falls sharply at around 18:00 in both flat and multi-rate profiles.

The weekend multi-rate profile is similar to that observed for flat rate participants with the addition of the morning peak. Table 4 shows the breakdown of customers in the industrial sector. There are roughly 3 times more flat rate participants to multi rate participants within the sample; therefore the aggregate sector profile is dominated by the flat-rate participants.

Average weekend consumption is relatively constant around 1kW, with an increase between around 06:00 and 13:00 with a peak at 11:00.

2.3.4 Office and Commercial

Office and commercial weekday and weekend profiles appear to have a similar profile shape, with reduced consumption in the weekend period seen in the flat-rate sample. The multi-rate sample shows the typical early morning peak. After this peak, the profile shows similarity between the multi-rate and flat-rate customers with consumption being significantly higher for the multi-rate participants. The main difference between the weekday and weekend profiles is a 'shoulder' on the weekday profiles in the period 16:00 to 18:00.

Similarity exists between the early and late morning profiles of this sector and the industrial sector, however post 18:00 consumption in the office and commercial sector does not show the same definite demand reduction.

The weekend profile for multi-rate participants shows an increase in demand as opposed to the reduction seen in other sectors, however since the number of commercial customers in the sample and the ratio of office to commercial is unknown this increased evening consumption cannot be accounted for in greater detail. The weekend peak for multi-rate customers in this sample also occurs later in the day in comparison against flat-rate customers.

The aggregate sector profile bears close resemblance to the flat-rate profile; this can be attributed to the greater number of flat-rate customers in the overall sector sample.

2.3.5 Public Sector and Other

Profiles for public sector and other follow a typical pattern for all cases (flat-rate and multi-rate), though the multi-rate sample shows the typical early morning peak.

Weekend consumption appears similar to weekday however with a reduction in consumption values. Maximum demand values occur typically around midday with a general reduction in demand after this period. A shoulder at around 18:00 leads to an increase in the rate of demand reduction.

2.4 Test Cell 3 Heat Pumps

A limited set of heat pump data from July 2012 to September 2012 was available from the Test Cell 3 monitoring trial start-up period. Although the set of participants is small, some observations can be made on broad average properties of the heat pump demand during the period. The available data is described as follows:

- Monitoring period 05/07/2012 to 30/09/2012, ramp up from 2 participants to 23.
- Actual number of participants with load data for entire month: 0 in July 2012, 5 in August 2012, 8 in September 2012. The five August customers were also in the September set.
- Heat pump participants were drawn from within Northern Powergrid's Northeast region.

10-minute average power data was averaged by month for all participants being monitored during that month; and separately by weekend and weekdays. Figure 13 shows average diurnal heat pump load profiles for August and September 2012. Figure 14 and Figure 15 show average diurnal heat pump load profiles for August and September 2012 respectively, split by weekday and weekend average.

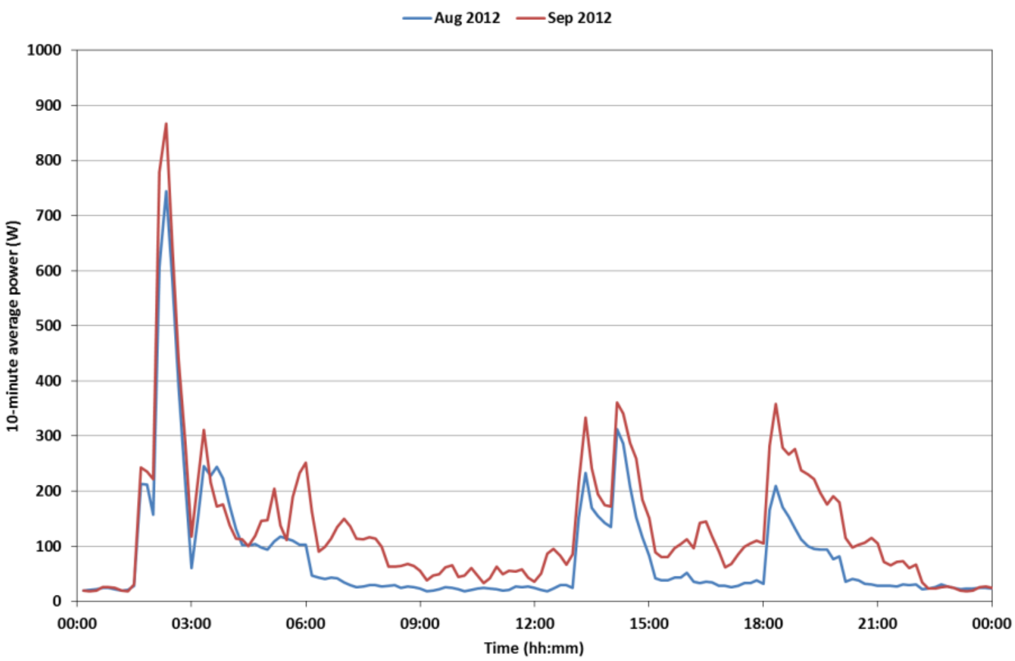

Figure 13 - Heat Pump average power for Aug / Sep 2012

Three load peaks appear to be evident in all of the profiles; at approx. 02.00, 13.00-14.00, and at just after 18.00. The 02.00 peak is reported to be a defrost cycle and is also very evident in the metering data. These peak periods will be studied in further detail as more data is collected in the monitoring trials.

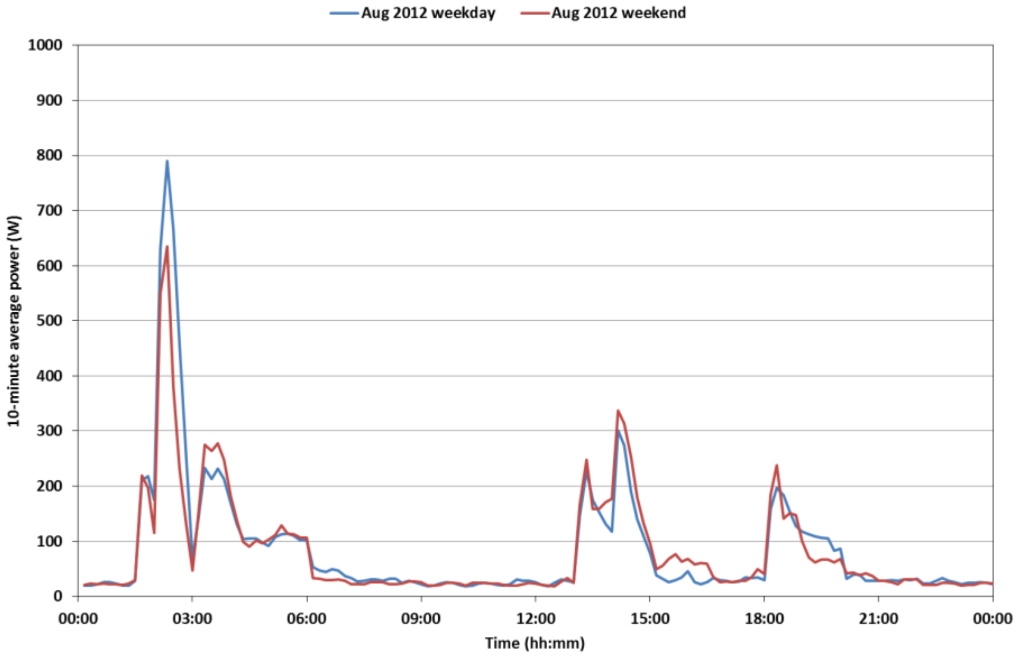

Figure 14 - Heat Pump average power Aug 2012, by weekday / weekend

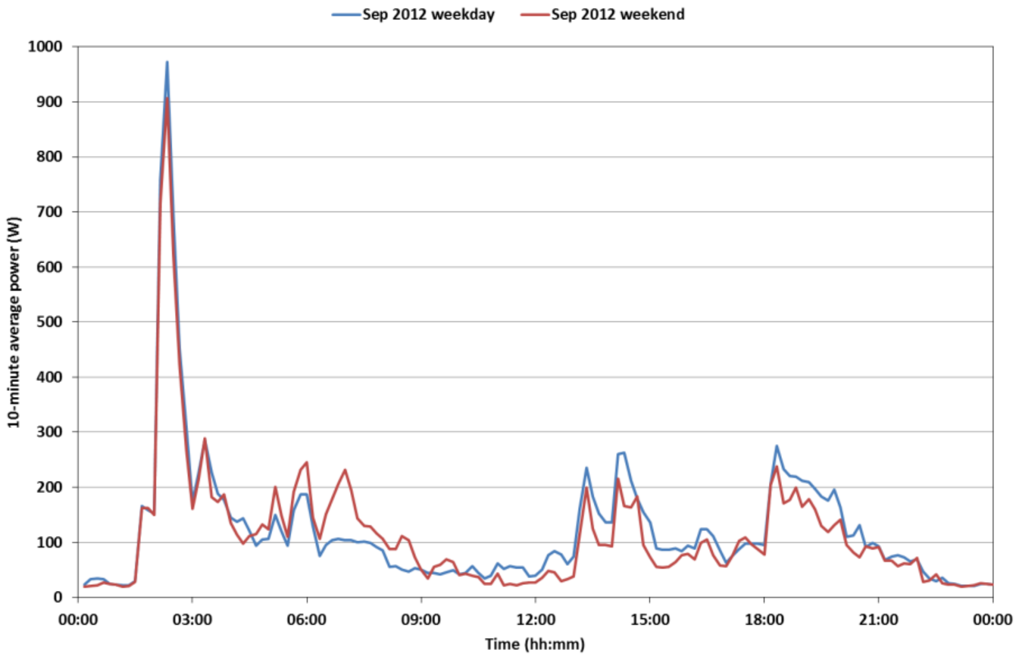

Figure 15 - Heat Pump average power Sep 2012, by weekday / weekend

2.5 Test Cell 5 & 20a Domestic PV

The test cell 5 solar PV trials start-up period began in May 2012 and a limited amount of monitoring data from July, August and September 2012 has been studied. Data from LO2 test cell 20a was also used, as PV output is independent of the intervention being trialled. The period between May and July was removed from the analysis as there were too few participants in the early start-up period. Any participants whose generation was not recorded for an entire month were also removed from the study. All customers were drawn from Northern Powergrid's operating region.

The numbers of PV arrays analysed is recorded in Table 5. Figure 16 shows the distribution of peak output (in W) for the generating arrays in the September sample. The median array peak export is 1900W and the most frequently seen installation is 2kW. Future work will investigate whether this is representative of the installed domestic PV base.

Month	TC 5	TC 20a	Total
July	5	6	11
August	15	15	30
September	46	37	83

Table 5 – Sample domestic PV customer numbers by month

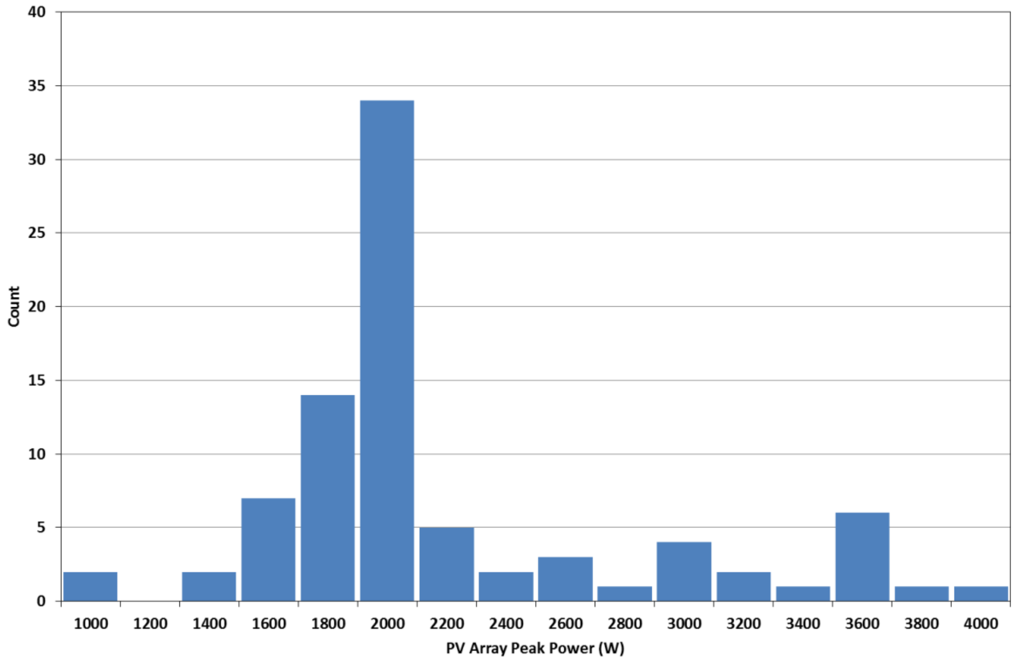

Figure 16 – Distribution of sample domestic PV peak export - September 2012

The data recorded from the participants' PV arrays are exported 10-minute average power. An informal inspection of the distribution of generation per 10-minute period showed that across an individual participant over a period of time, and across multiple participants on the same day, the distribution of exported power is frequently positively-skewed, and sometimes bimodal. This was the case for both power and capacity factor (defined as the 10-minute average power divided by the peak output of that generator). Capacity factor was studied as the random variable rather than the absolute power output in order to standardise for peak generation capacity.

Figure 17, Figure 18 and Figure 19 show the median and 5% and 95% percentiles of the export capacity factors for the July, August and September generation groups respectively; there is evidently very similar export performance per month for the samples studied, and the effect of the changing seasons can be seen in the narrowing of the profile in the later months. Peak output is achieved rarely, and there is also demonstrably a residual generation at mid-day irrespective of the month, i.e. for 19 days out of 20, solar generation on the network will be greater than around ~5-8% of the installed capacity at peak. Note that the small amount of power consumed by the inverters during night-time hours is real.

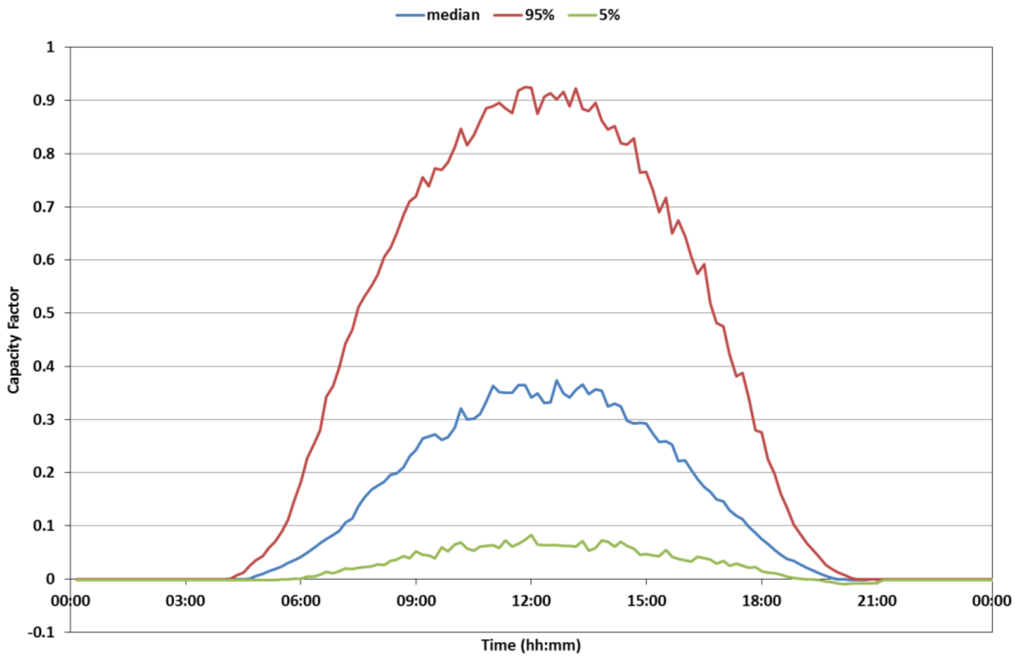

Figure 17 – Distribution of capacity factor for 11 domestic PV generators, July 2012

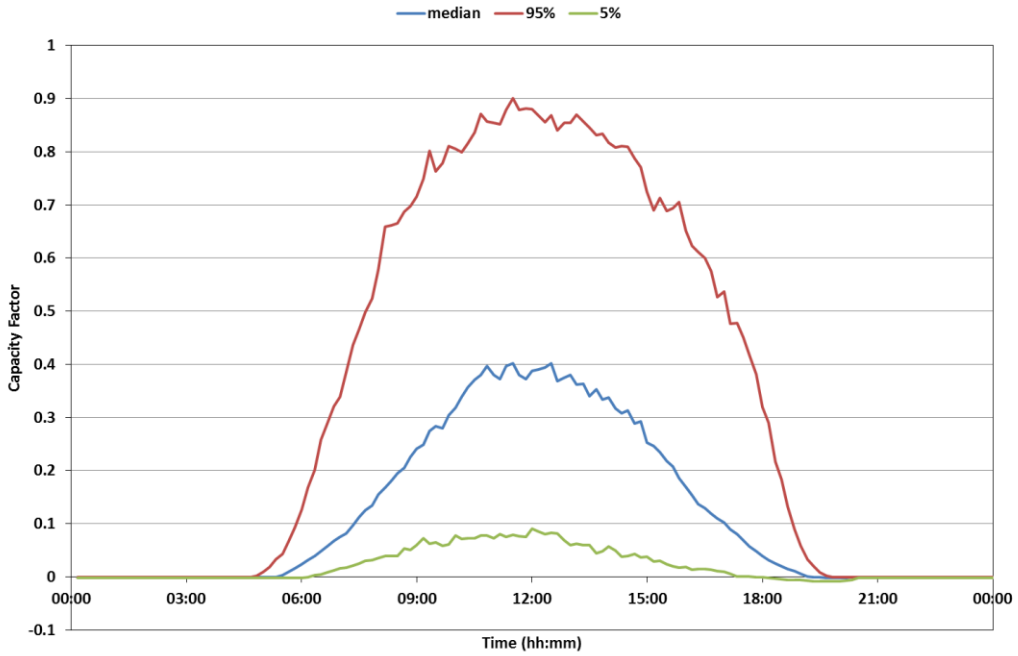

Figure 18 – Distribution of capacity factor for 30 domestic PV generators, August 2012

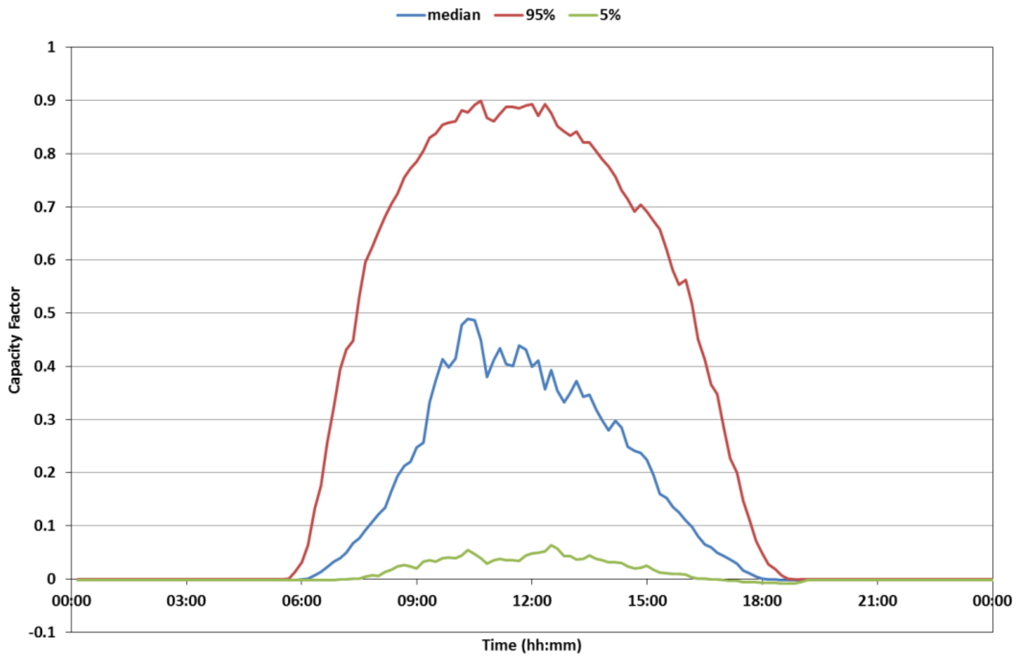

Figure 19 – Distribution of capacity factor for 83 domestic PV generators, September 2012

Figure 20 shows the median capacity factor during July 2012 for 11 generating arrays, with the heavy red line showing the median for all of the generators (from Figure 17). Although variation across PV sites caused by building orientation, location and weather, and installed capacity will be seen, the relative consistency of PV profiles suggests that a single generation profile class will be sufficient to characterise PV, when considered in aggregate. It is unlikely that PV output will depend upon the customer type except perhaps with respect to the installed capacity. It must be noted however that the PV arrays involved in the study come from a relatively wide geographic area and thus from a variable set of local weather conditions. At the LV level, i.e. individual streets, PV export may be more highly correlated on a daily basis, and this will require further study.

Further work will involve the study of the complete LO1 test cell 5 dataset, to reinforce this preliminary investigation with larger and consistent participant numbers, and a view of annual and regional variation.

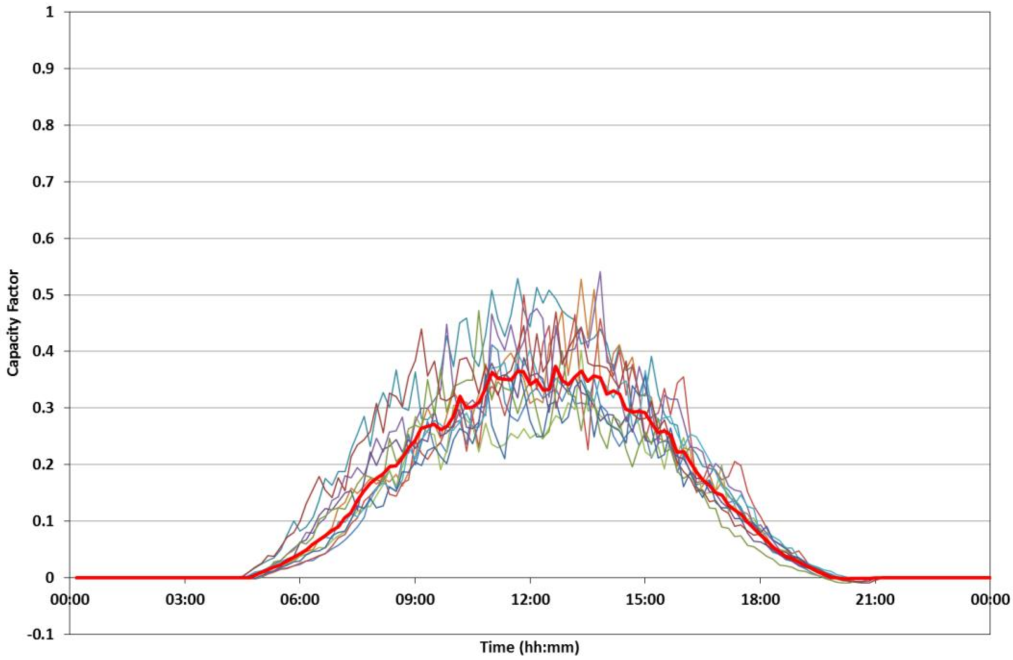

Figure 20 - Median capacity factor for 11 PV generators for July 2012 – individual and aggregated

2.6 Test Cell 6 Electric Vehicles

Two electric vehicle users were monitored as follows:

- EV1 between 11/05/2012 and 31/09/2012 (however the EV owner doesn't appear to have started home charging before 06/07/2012)
- EV2 between 14/08/2012 and 31/09/2012

Average power per 10-minute interval was collected. Figure 21 shows a plot of the relative likelihood of the EV charger being active during each 10-minute period, i.e. the total number of times the charger was used in each 10-minute period, scaled by the total number of 10-minute periods when the EV was charging, for each EV user. While charging, electrical demand was roughly constant at 3750W for EV1 and 2440W for EV2). Two trial participants alone are insufficient to form a general picture of EV domestic charging patterns and further analysis will be conducted when more data is available. It is evident however that there is a disparity of behaviour even between the two EV users presented, with EV2 charging primarily at night and EV1 creating a charging peak at 19.00; the regularity of both suggesting the use of a timer.

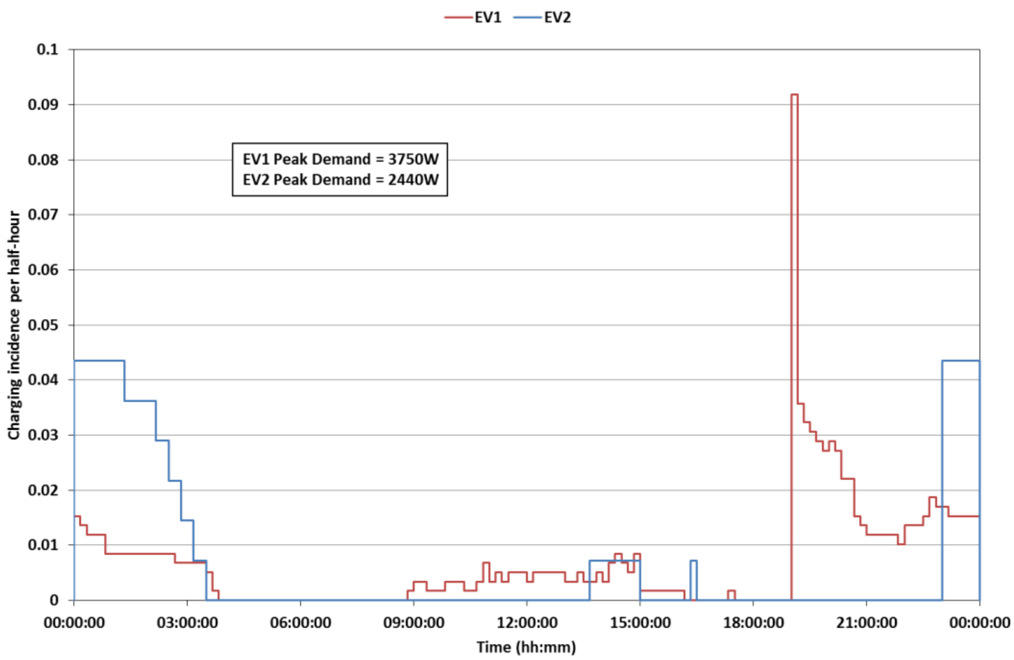

Figure 21 – Relative frequency of EV charging per half hour

Figure 22 and Figure 23 show a breakdown by weekday and weekend of charging time incidence per EV user. The pattern of EV charging for these two users appears to be very similar irrespective of the day; the charts are not normalised to the number of days in each category, so we would expect 2.5 times more weekday charging to take place than weekend. This analysis does not consider that frequent short (<10 minute) charging periods (which occur with EV1) will look the same as infrequent long charge periods and the true power drawn for short charging may not be accurately reflected – thus a frequency plot may overestimate the EV charging demand.

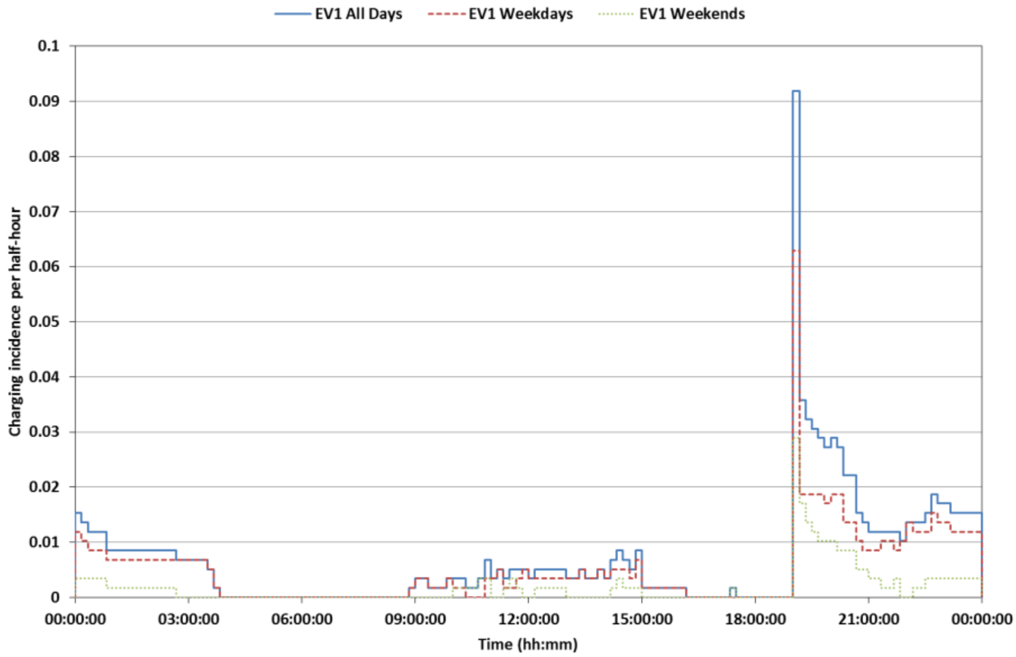

Figure 22 - EV1 Weekend and Weekday charging

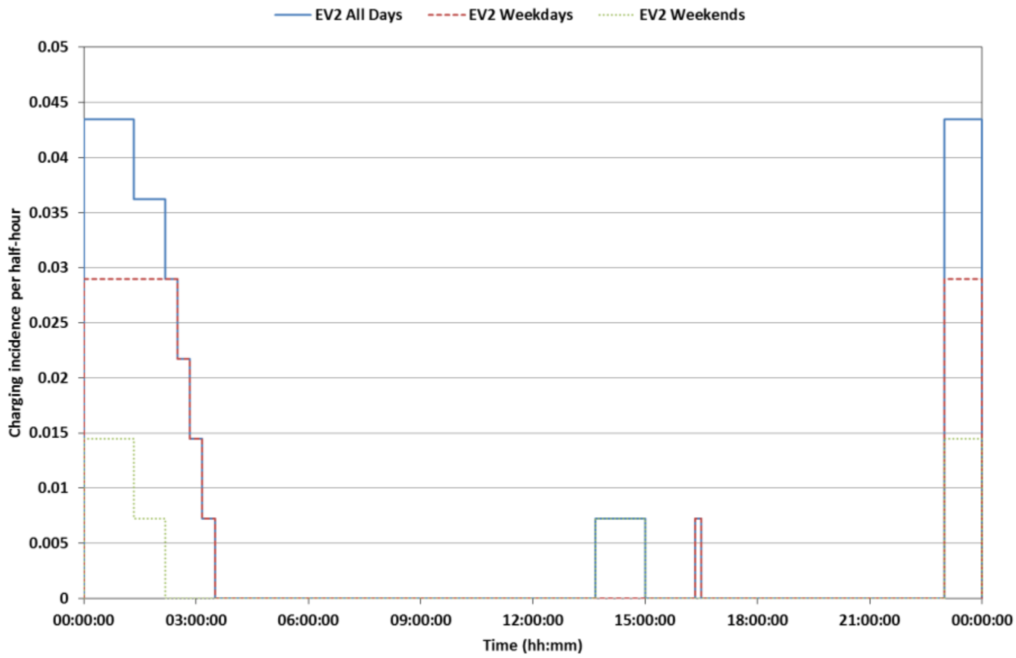

Figure 23 - EV2 Weekend and Weekday charging

2.7 Test Cell 8 I&C Distributed Generation

2.7.1 Overview

Test Cell 8 is comprised of distributed generation (DG) in the Northern Powergrid network area that falls under G59 connections; these customers are monitored half-hourly and the data is provided by Northern Powergrid directly. The aim of this test cell is to establish a new set of generation profiles to update ETR130 in order to improve recognition of the contribution of DG to system security, and this initial study is oriented towards understanding whether general classes of generators do in fact exist and are meaningful. No interventions such as time of use tariffs or load control are present for these customers.

The planned[7] test cell size is 230 participants; this was defined with reference to the number of known DG customers within Northern Powergrid's operating area. The actual amount of data available for analysis is reduced from this number, as follows.

Total number of files in the sample provided by Northern Powergrid is 603. Files are per customer, span the duration of the trial, and are categorised as EXP-MW, MW and MVAr. MVAr files have not been used in this analysis as this study is concentrating on real power export. On inspection, a number of MW files were found to be site export values and have therefore been included in the sample. All EXP-MW files were included.

The remaining number of files suitable for analysis after filtering is 160. A large number of files contained either no recorded data or highly sparse quantities of data and were therefore removed from the sample.

Data has been split into both operating regions of Northern Powergrid (Northeast, and Yorkshire). These data were then classified by generation type. All files consist of half hourly average power data for the period 01/03/2009 to 20/04/2011.

[7] I.e. as defined in the CLNR submission, Appendix 4 page 52

Northern Powergrid (Northeast)	**No. of sites in total sample**	**No. of sites analysed after erroneous datasets removed**
Wind farm	109	30
Landfill	98	42
Hydro	10	3
Cogeneration	289	29
Total (Northeast)	**506**	**104**
Northern Powergrid (Yorkshire)	**No. of sites in total sample**	**No. of sites analysed after erroneous datasets removed**
Wind farm	9	7
Landfill	20	20
Hydro	0	0
Cogeneration	68	29
Total (Yorkshire)	**97**	**56**
Total (all Northern Powergrid)	**603**	**160**

Table 6 – Datasets available for TC8 analysis

2.7.2 Analysis Method

For each DG type, half-hourly capacity factors have been calculated, in order to create a "generation profile". In order to calculate the half hourly capacity factors all data has been averaged across the entire data period based on daily, weekend and weekday consumption. Analysis of individual days in addition to weekday and weekends has been carried out to investigate if patterns of usage exist for generation sources which contain a human factor i.e. sources where fuel is loaded manually, or net cogeneration export differences based upon time of day, as opposed to wind generation which is assumed to be operational 24/7.

The main focus of the work presented here has been an attempt to produce a characterisation of "generation profiles" in general, since the concept of a generation profile is not well defined. Monthly averages have not been calculated at present; however future analysis will investigate seasonal variation, in particular for wind generation.

2.7.3 Wind Farm Generation Profiles

Half-hourly capacity factors for wind generation sites in the Northern Powergrid (Northeast) area are shown in Figure 24. A similar diurnal pattern of generation appears present within the datasets analysed, however no comment upon capacity factors for each site can be made at this time. Anomalous datasets have been included for completeness; however will be commented upon separately.

Wind farm 07796 – 104 days (of a possible 781) with no recorded output from the wind farm

Wind farm 13152 – 134 days with no recorded output. On further investigation it was found that this wind farm has a known history of faults, resulting in minimal generation output.

Wind farm 14084 – Commissioned late into the monitoring period, therefore a limited dataset was available to calculate a generation profile.

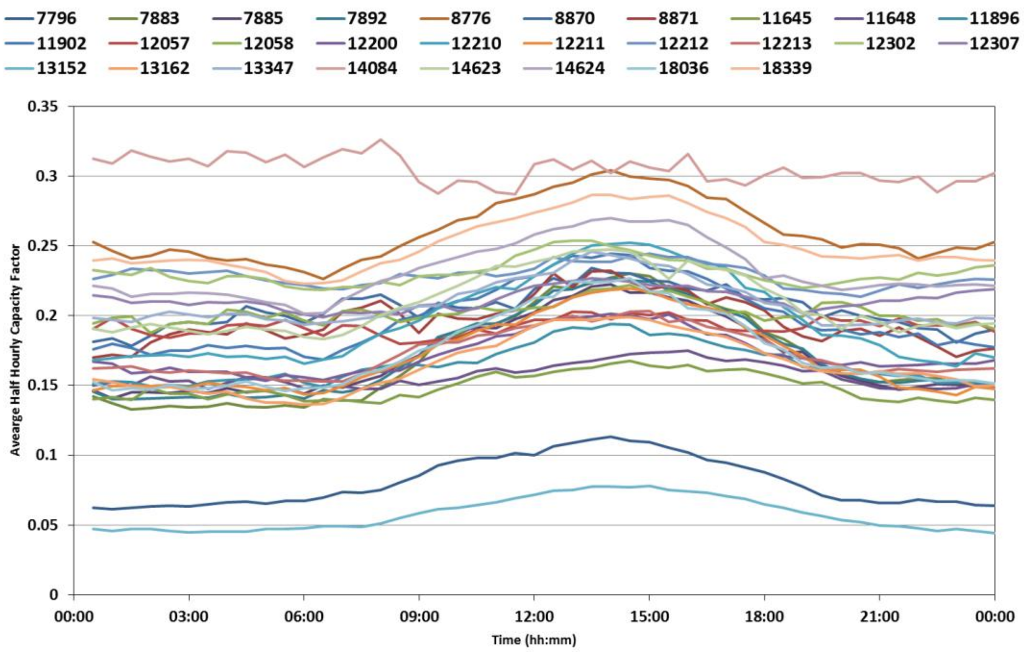

Figure 24 – Half-hourly capacity factors for wind farms in the Northern Powergrid (Northeast) area

Half-hourly capacity factors for wind generation sites in the Northern Powergrid (Yorkshire) area are shown in Figure 25. A similar diurnal pattern consistent with that shown in Figure 24 is apparent. Anomalous datasets have been included for completeness; however these will be commented upon separately.

Wind farm 21854 – This wind farm has been reported as functioning at a minimal percentage of its installed capacity. This is clearly reflected in the capacity factor results.

Wind farm 43358 – Commissioned late into the monitoring period, therefore a limited dataset was available to calculate a generation profile.

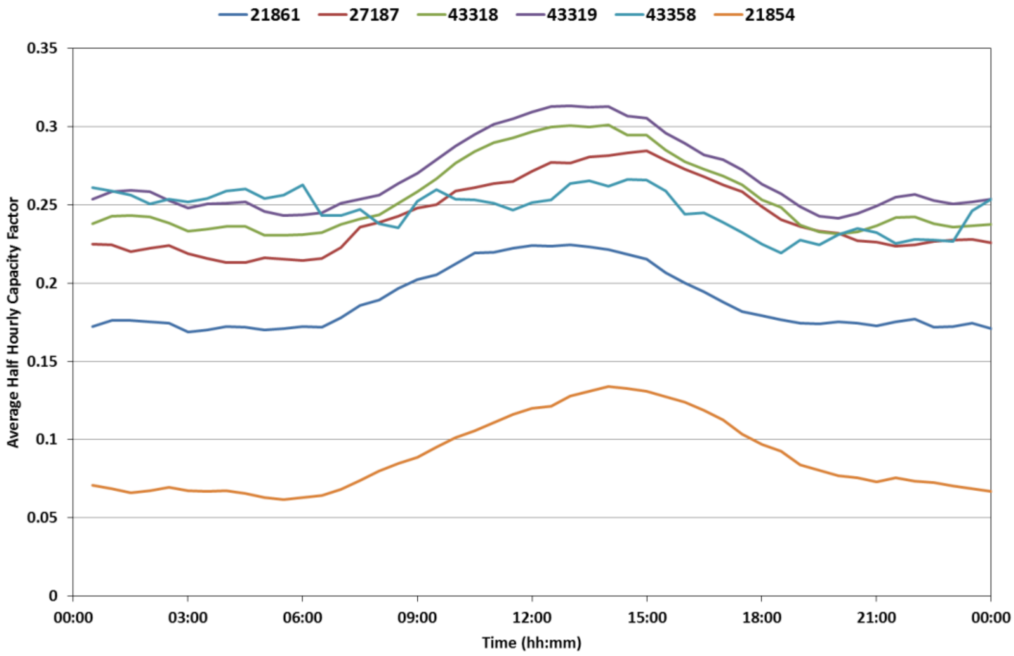

Figure 25 – Half-hourly capacity factors for wind farms in the Northern Powergrid (Yorkshire) area

It should be noted that for wind farms which were commissioned late into the sample period, only data from the in-service period has been used.

2.7.4 UK Met Office Data analysis

In order to quantify the diurnal variation in wind farm output, hourly weather data from the UK Met Office[8] has been analysed for two locations, one in each Northern Powergrid license area. Data covered the period 01/03/2009 to 02/02/2012. The sites are:

- Northern Powergrid (Northeast) – Met Office site: Albemarle
  - Latitude: 55.0197 Longitude: -1.88012
- Northern Powergrid (Yorkshire) –Met Office site: Bramham
  - Latitude: 53.8687 Longitude: -1.31722

The results of this analysis are shown in Figure 26.

[8] UK Meteorological Office. Met Office Integrated Data Archive System (MIDAS) Land and Marine Surface Stations Data (1853-current), [Internet].NCAS British Atmospheric Data Centre, 2012, 19.12.12. Available from http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_ukmo-midas

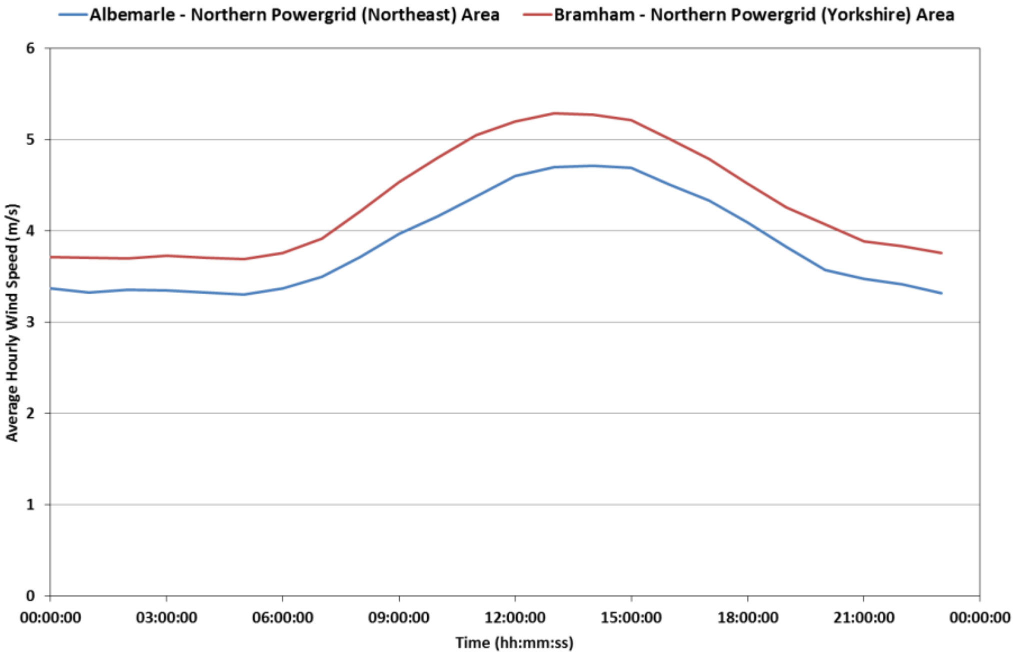

Figure 26 – Average hourly wind speeds for two Met Office sites

The chart above shows similar diurnal pattern for average wind speeds for the two sites considered. Figure 27 shows this data plotted against average hourly capacity factors for all wind farms across both licence areas. No conclusions have been drawn between wind farm capacity factor and average wind speed at this time.

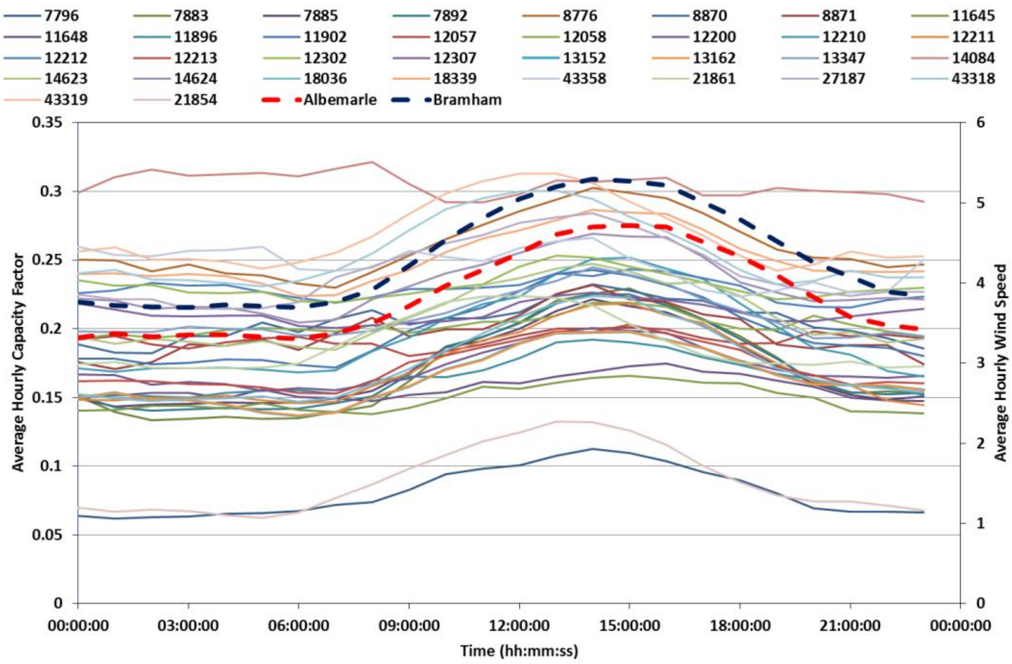

Figure 27 – Average hourly capacity factors against average hourly wind speeds from two Met Office sites

2.7.5 Landfill Generation Profiles

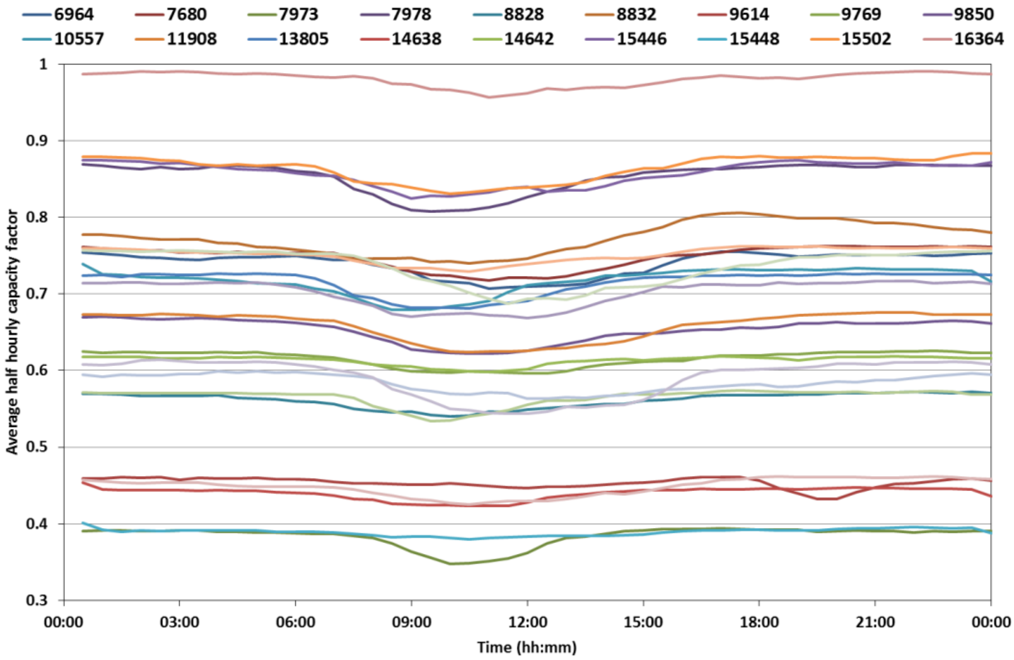

Figure 28 – Half-hourly capacity factors for landfill generation in the Northern Powergrid (Northeast) area

Figure 28 shows the average half-hourly capacity factors for landfill generators in the Northern Powergrid Northeast area. As for wind farm generation, a typical profile is apparent for many sites; a period of uniform export between the hours of 17:00 and 07:00, with a reduction in output in the interim period. The characteristic profile on visual inspection is however less homogenous than has been observed for wind generation. Figure 29 shows the results of the same analysis on data from the Yorkshire area.

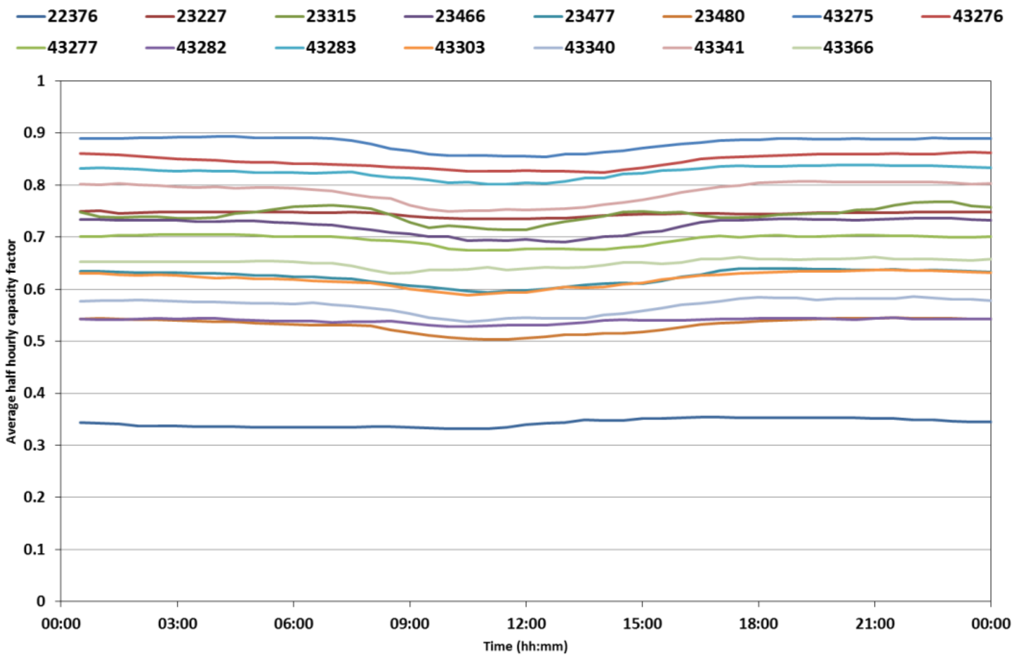

Figure 29 – Half-hourly capacity factors for landfill generation in the Northern Powergrid (Yorkshire) area

Similar profiles to those derived for Northeast landfill sites have been observed for the Yorkshire datasets. Again, as per wind generation data, no conclusion with regards to specific capacity factors has been drawn as part of this analysis.

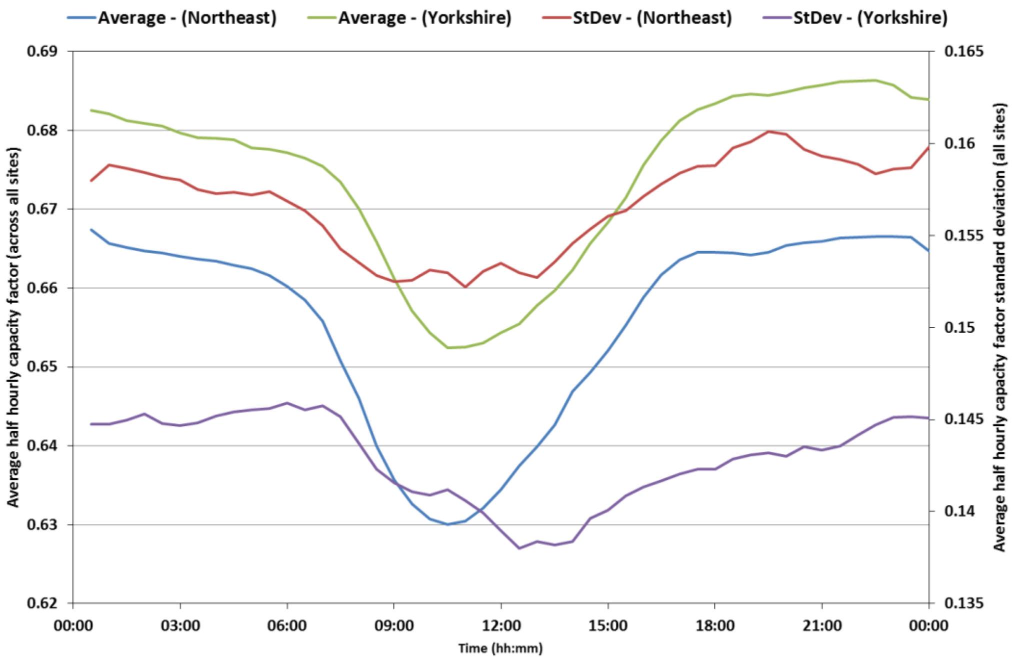

Figure 30 – Average and Standard deviations across all landfill generators in Northern Powergrid licence areas

Figure 30 shows the derived half hourly capacity factors and standard deviations for an average of all generators in the Northeast and Yorkshire areas. The correlation coefficient between the two average profiles is 0.98, indicating a good correlation between results in each area, and in addition provides an indicator as to the robust nature of a generation profile for landfill gas sites.

It is important however, to note that landfill sites are unlikely to deliver a similar export contribution to the network at all times, i.e. for both weekday and weekend periods, as opposed to, for example, wind farms. Figure 31 shows the result of analysis of profiles derived for individual days of the week, in addition to aggregate weekday and weekend profiles.

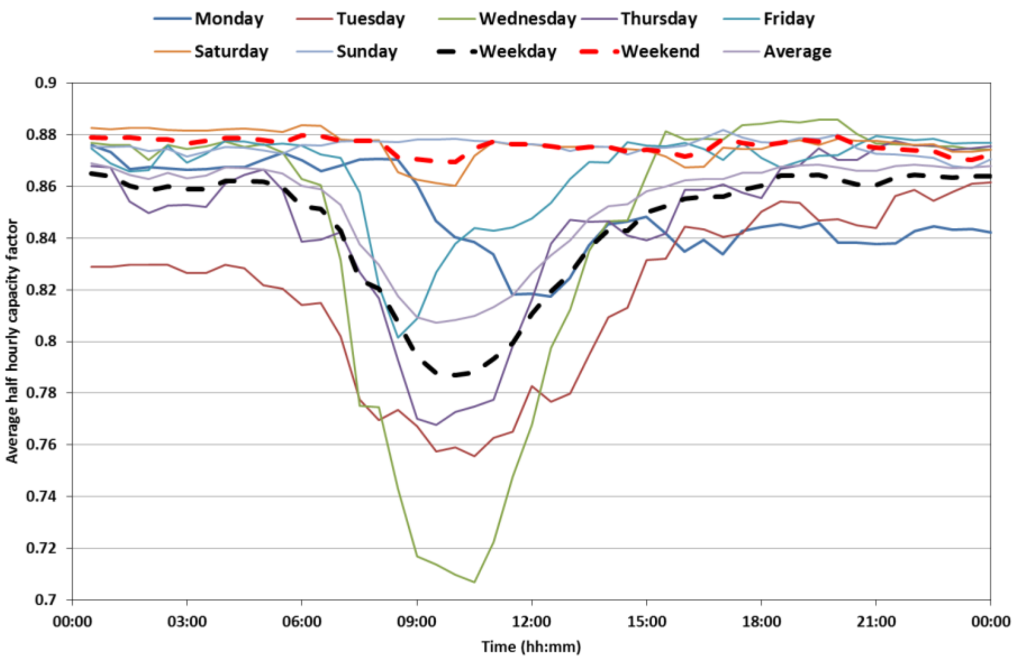

Figure 31 – Half-hourly capacity factors for individual days for one landfill generator

Weekday export can be seen to decrease significantly in the period from around 06:00 to 15:00, whereas weekend export remains at an almost constant level. A hypothesis for this result is simply that the on-site generation is used to power on-site load during weekdays (typical working week) with reduced load in the weekend period resulting in a more uniform export profile. Figure 32 shows a replication of this analysis across all sites in the Northern Powergrid area.

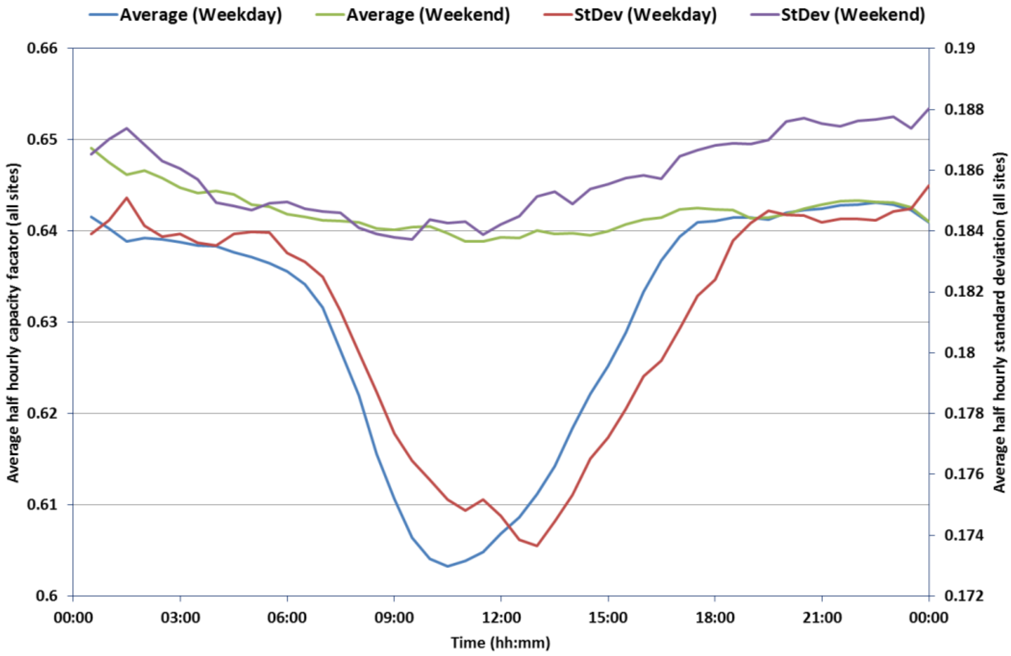

Figure 32 – Half-hourly capacity factors for individual days for all landfill generators in the Northern Powergrid area

2.7.6 Hydro

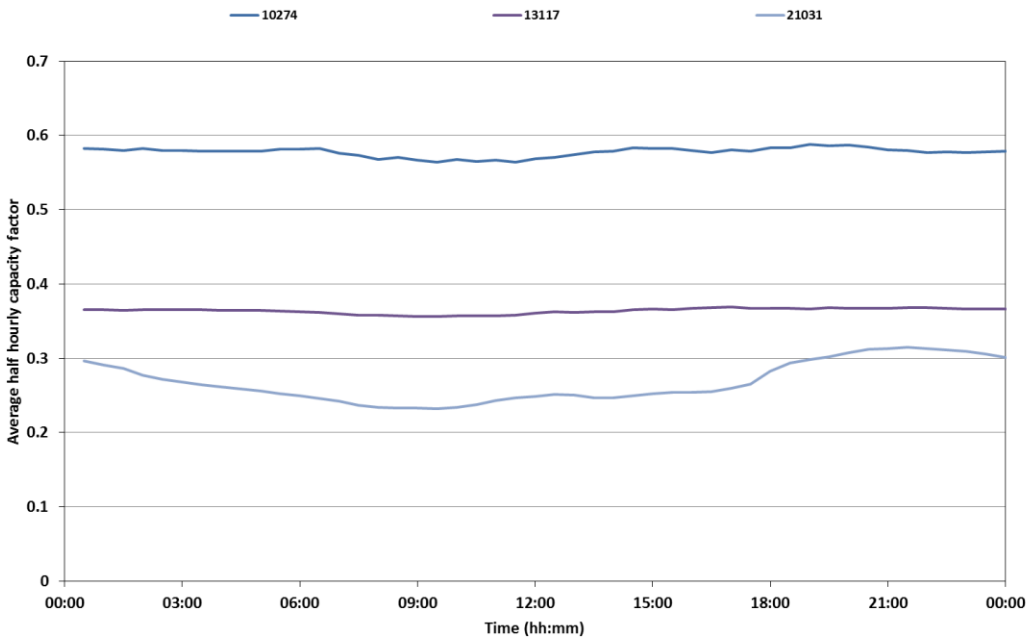

Figure 33 – Half-hourly capacity factors for hydro generation in the Northern Powergrid (Northeast) area

Figure 33 shows half hourly capacity factors for hydro generation in the Northern Powergrid (Northeast) area. Output appears relatively constant for sites in the sample; however limited conclusions can be drawn due to the small number of customers in the sample.

2.7.7 Cogeneration

Cogeneration, hereafter referred to as cogen, in the context of this report has been defined as any site which generates an export quantity and did not come under the explicit category of wind, landfill or hydro plant upon preliminary analysis. Perhaps the most common form of cogen is in the export from combined heat and power (CHP) units. Clustering of cogen was initially carried out on a 'per-sector' basis for the data supplied with revisions made where necessary.

An example of a typical revision was an EXP-MW file categorised as a quarry. Upon analysis the generation profile for the site appeared to correlate well with the previously derived wind farm profiles. Upon investigation the quarry was found to have installed a wind turbine at site. The site was therefore reclassified.

Not all cogeneration sites have been detailed in this report. Additional results from the sample can be found in the datasets which accompany this report. This report aims to detail some of the major findings arising from this analysis.

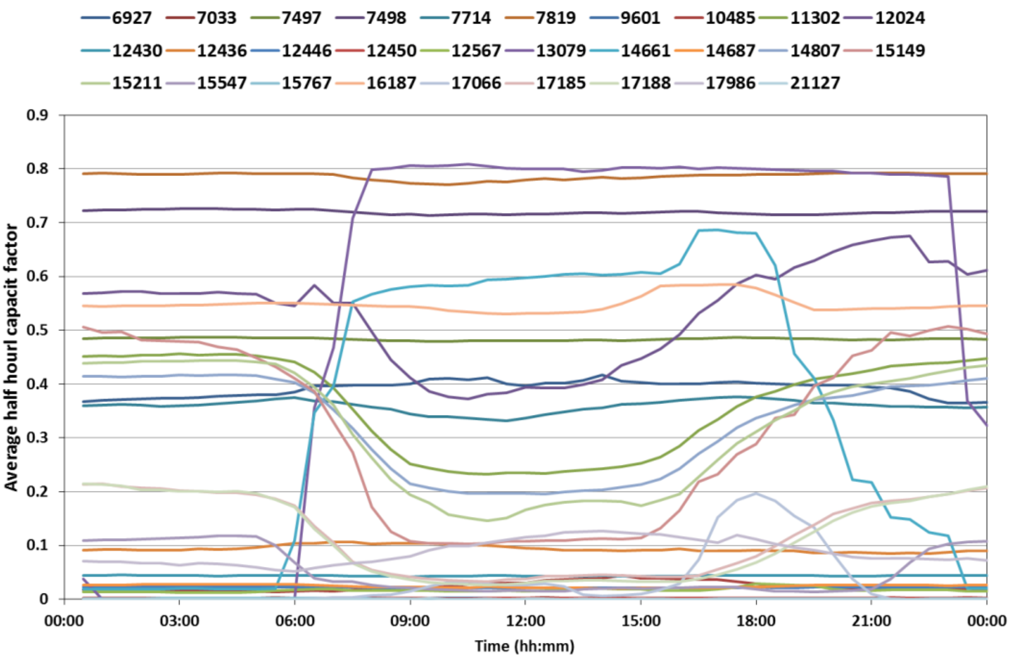

Figure 34 - Half-hourly capacity factors - all Northeast generators

As a preliminary form of analysis half hourly capacity factors were calculated for all cogen sites and then plotted. Figure 34 shows the results of this analysis for the Northeast area sample. This figure shows similarity between certain profiles, with three main clusters being apparent. It is important to note that the general shape of the profile has been used as the primary identifier as opposed to the values of capacity factor or information on the type of industrial or commercial business. The three main clusters are:

- Cluster A - Almost constant capacity factor for 00:30 to midnight
- Cluster B - A significant reduction in capacity factor between 09:00 and around 15:00
- Cluster C - An increase from almost 0 capacity factor to maximum at around 06:00.

A number of outlier profiles are also present and were analysed separately.

2.7.8 Cluster A

Figure 35 shows capacity factors for all sites which were classified as being of type cluster A. When sites were compared against their actual classification information all sites were found to be within the manufacturing sector. Without further information on the type of devices or individual practices it is not possible to comment further upon the resultant profile. However similarity between sites suggests that a manufacturing sector cogen profile may be possible.

Similar results to those found for Northeast samples have been observed for sites in the Yorkshire sample.

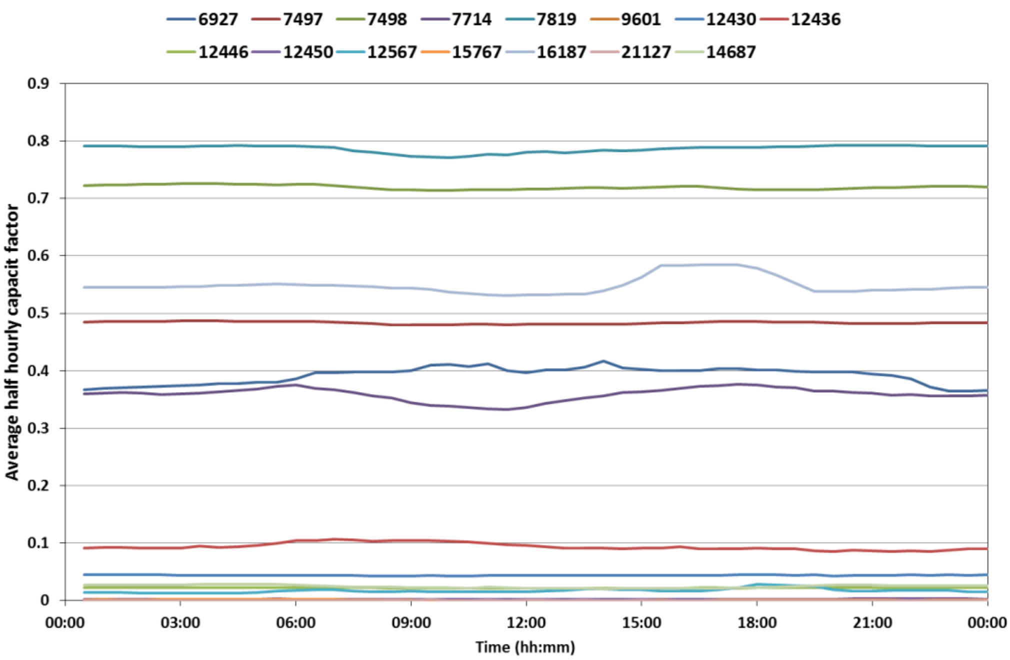

Figure 35 – Half hourly capacity factors for Cluster A sample (Northeast)

2.7.9 Cluster B

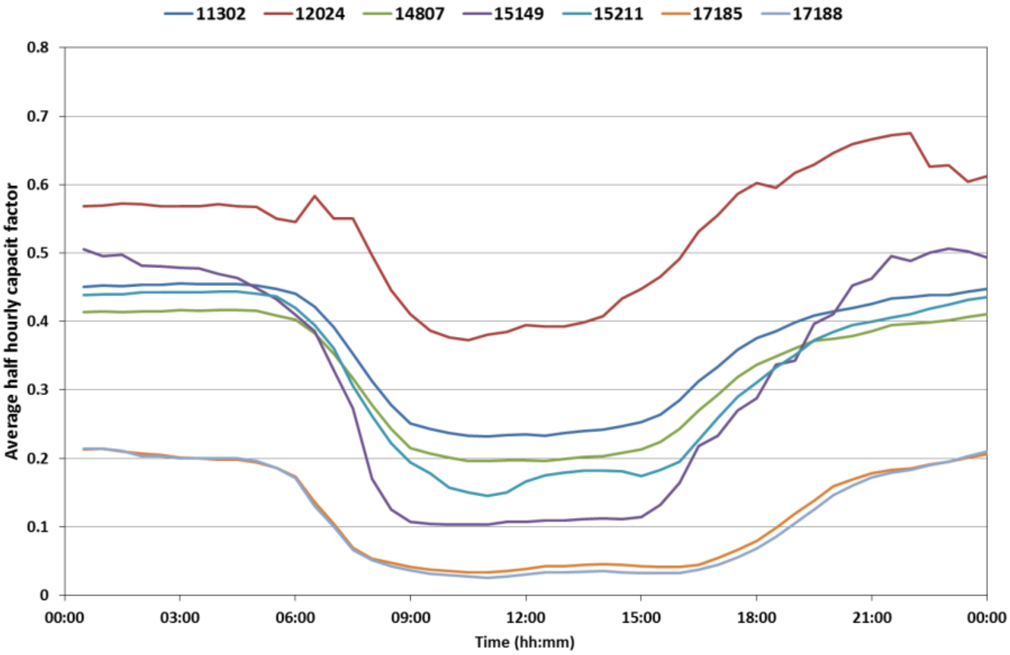

Figure 36 – Half hourly capacity factors for Cluster B sample (Northeast)

Figure 36 shows the half hourly capacity factors for the cluster B sample. Capacity factors are reduced on average between the hours of 09:00 and 15:00. On further investigation all sites in this cluster were found to be hospitals. CHP units have been installed at a number of hospitals across the North East and Yorkshire as part of wider cogeneration schemes to reduce electricity import from external sources.

A potential rationale for the reduction in capacity factor during the period 09:00 to 15:00 is the on-site netting off of demand by the installed cogeneration scheme. At times of reduced demand on site, export is increased, reflected in the increased capacity factor. Figure 37 shows the profiles for one typical Northeast site for each day of the week, with weekday, weekend and average profiles also shown.

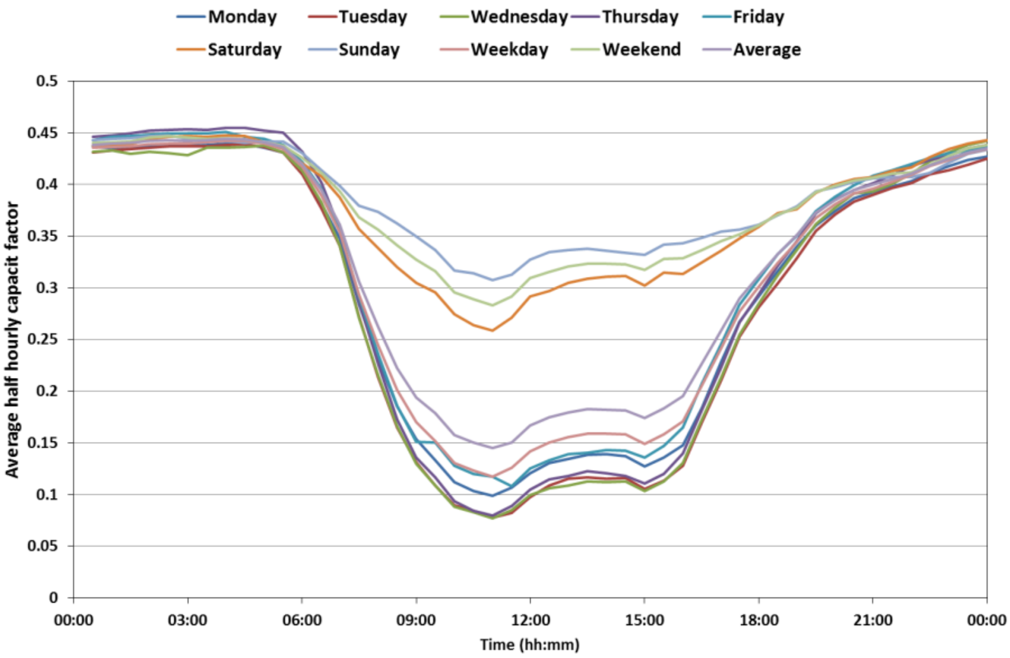

Figure 37 – Typical hospital cogeneration profile (Northeast area)

The Yorkshire data sample contains only one hospital with the data shown in Figure 38. On comparison there are definite similarities in the shape of the profile, with both sites displaying an increase in capacity factor in the weekend period. A peak at around 18:00 for the Yorkshire site provides the greatest difference in profile between the sites.

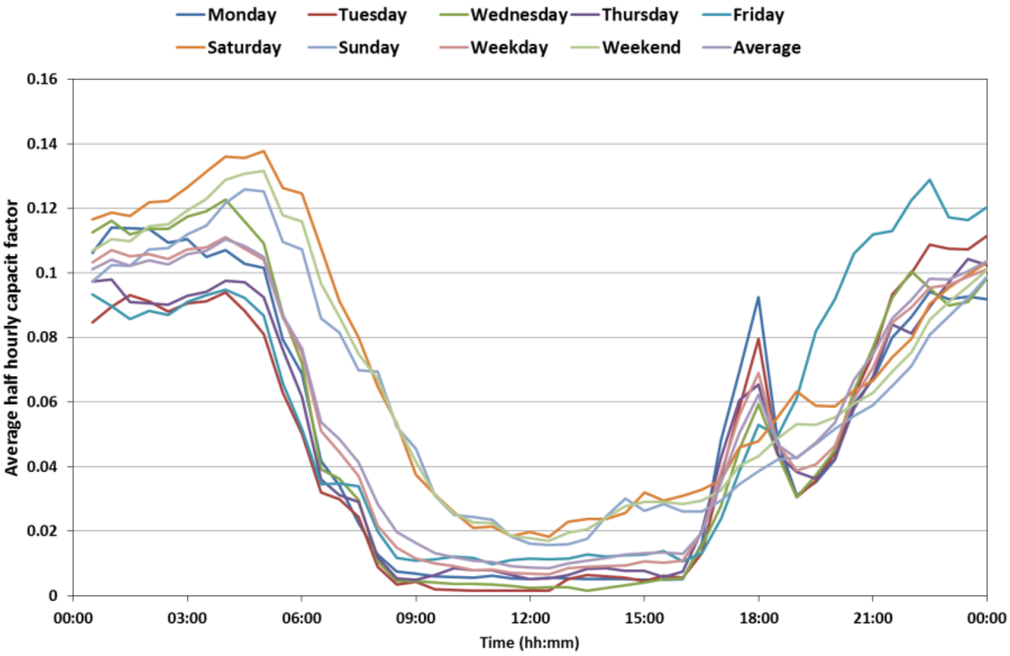

Figure 38 – Yorkshire area hospital cogeneration profile

2.7.10 Cluster C

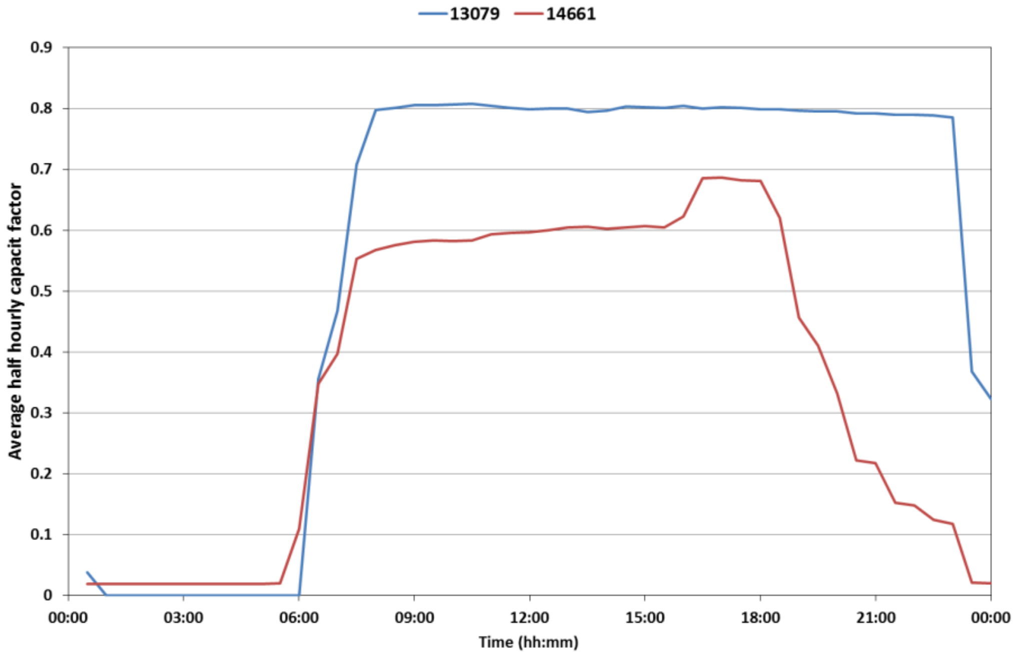

Figure 39 – Half hourly capacity factors – Cluster C sample (Northeast)

Figure 39 shows the half hourly capacity factors for the sample of cluster C sites. On inspection a rapid increase in generation at around 06:00 leads to an almost constant peak output for both sites, however after this point, the profiles are significantly different. Site 13079 represents the export from a boiler house in a block of flats, while site 14661 shows export for a garden nursery business. Both Northeast and Yorkshire samples contain boiler house export sites. The profiles for these sites are shown in Figure 40 and Figure 42 respectively.

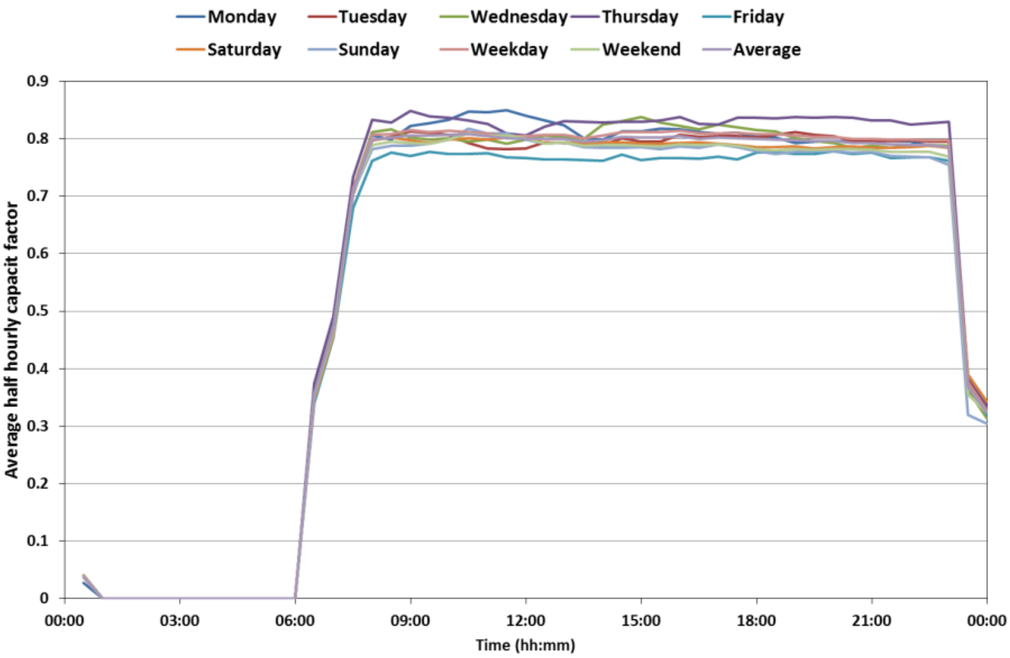

Figure 40 – Northeast boiler house

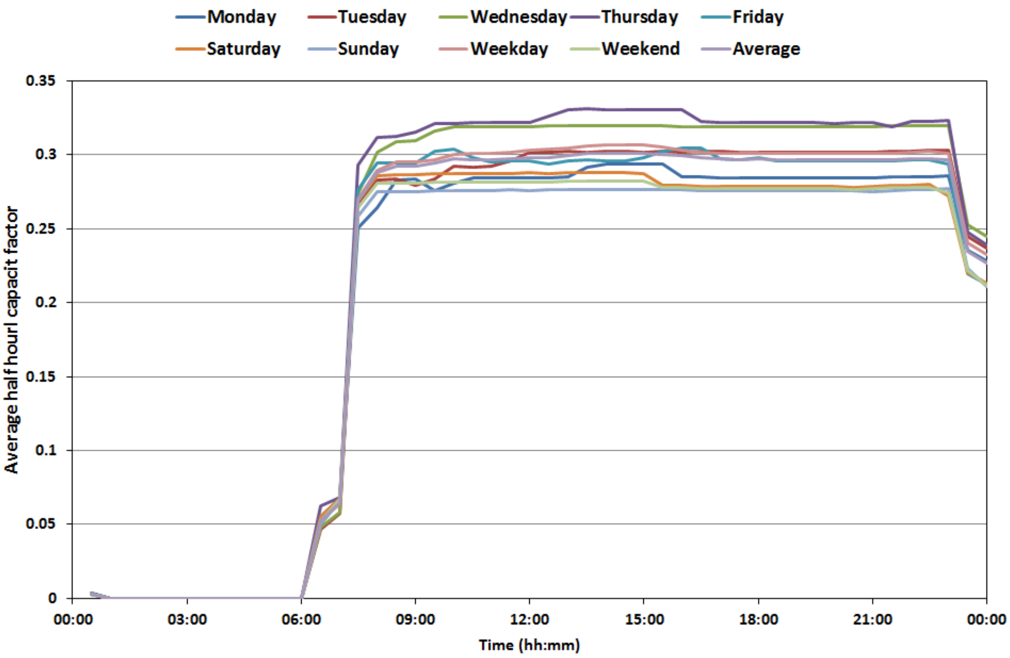

Figure 41 – Yorkshire boiler house

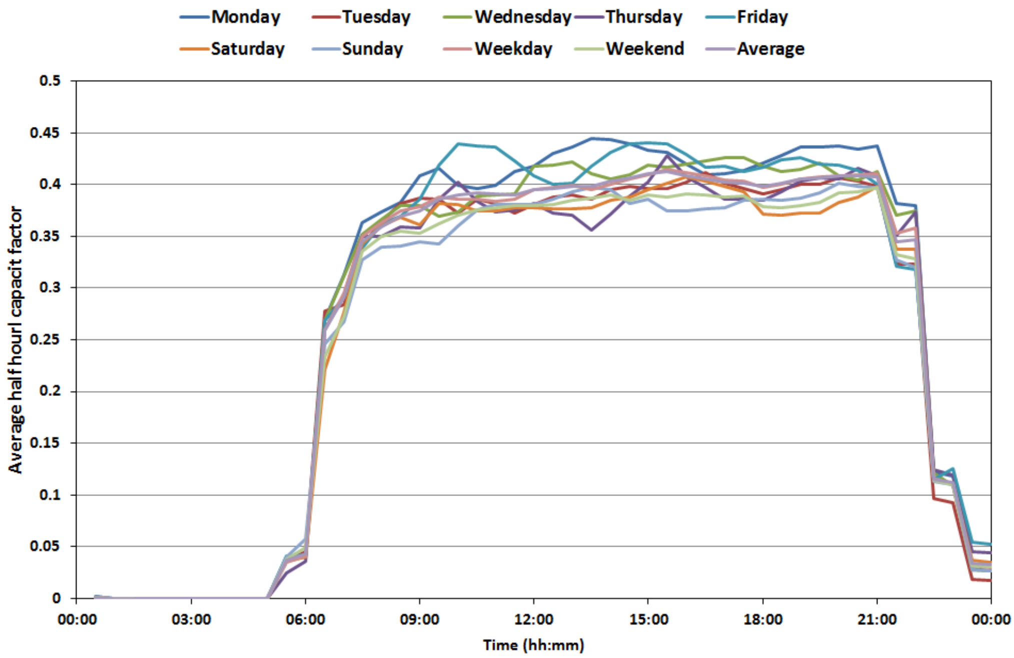

Figure 42 –Community heating scheme (Biomass)

The Yorkshire area boiler house site shows similarity to the profile for the Northeast sample. Figure 42 shows profiles for a community heating scheme which on further investigation refers to the export from a biomass generator. More detailed information on the Northeast and Yorkshire boiler house sites is unavailable at present; however definite similarities exist in the shape of the profile, whilst the Northeast site has a significantly greater capacity factor in comparison to the other sites.

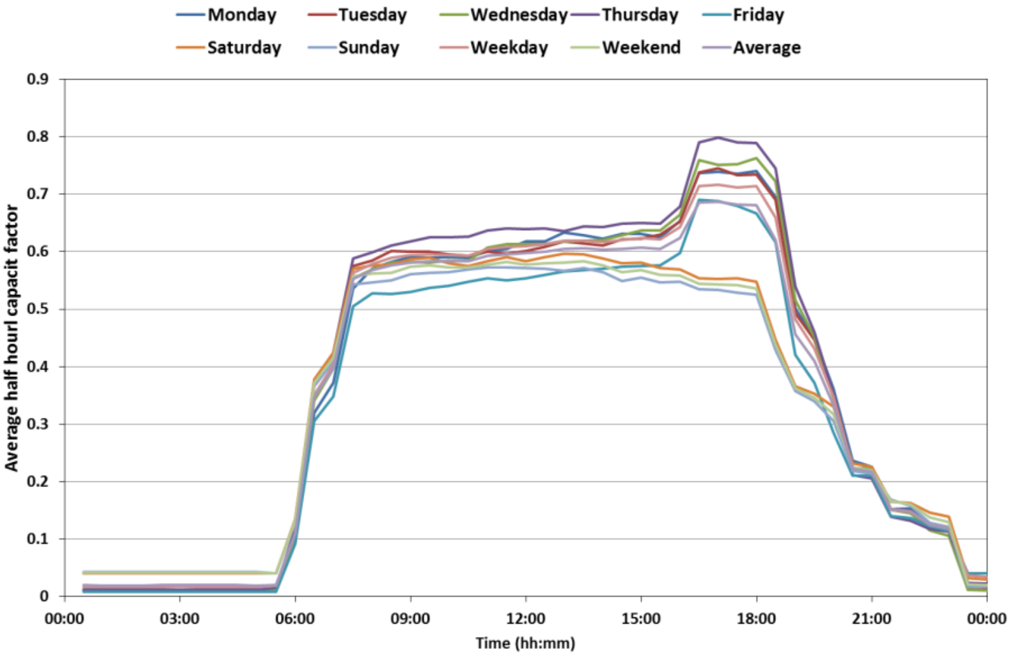

Figure 43 – Northeast Nursery

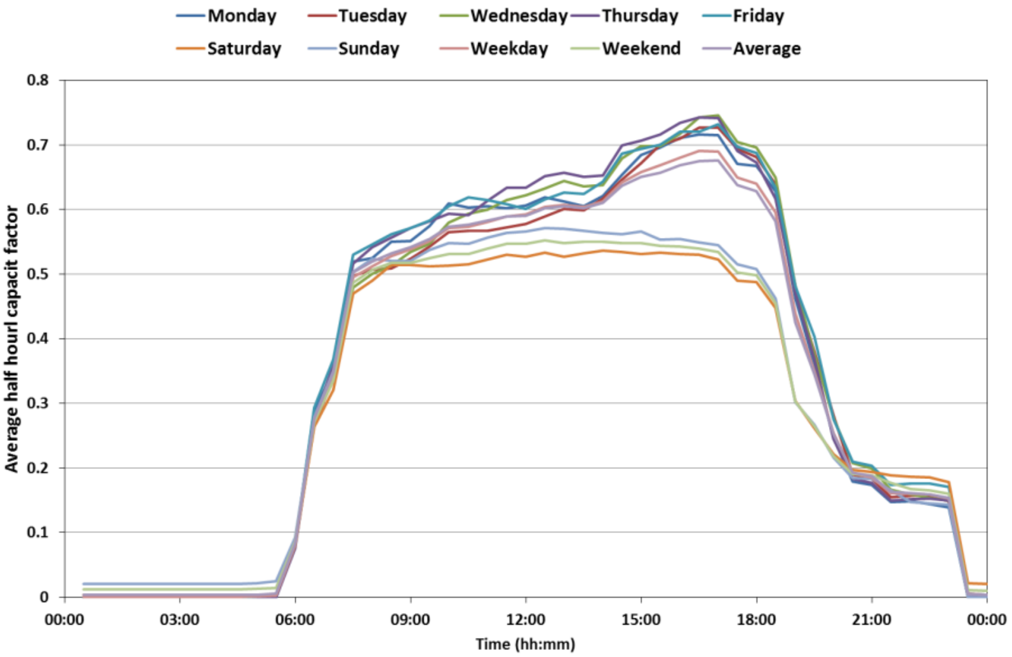

Figure 44 – Yorkshire Nursery

Figure 43 and Figure 44 show results for garden nurseries in the Northeast and Yorkshire areas. Similar profiles can be seen for both profiles, with a characteristic increase in generation output at both sites between around 15:00 and 18:00 during the Monday-Friday period. Weekend export appears similar at both sites. Further investigation is required to understand business practices at these sites. For the

Northeast site, the characteristic generation increase occurs at the exact same time for each day in the weekday period, perhaps indicating that an additional load is removed on a timer.

2.7.11 Non-clustered sites

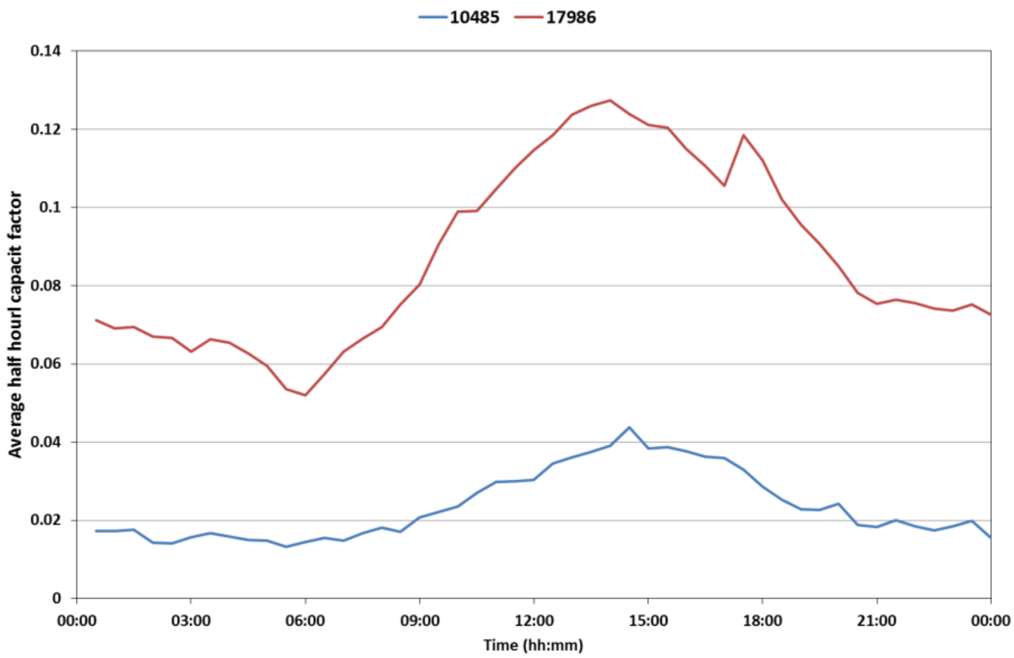

Figure 45 – Half hourly capacity factors – non clustered sites

Sites 10485 and 17986 (Figure 45) show significant similarities to previously derived wind farm profiles. The sites have not been reclassified since they do not represent actual merchant generation; rather they are sites which have installed a wind turbine at site. Site 10485 is a primary school with an installed turbine, where 17986 is an office block with a wind turbine installed on the roof. These sites have been included in this report as they represent an example of the need for greater information on site composition if accurate clustering and profiling is to be carried out.

3 Conclusions

3.1 Summary

This report details the initial findings of analysis of metering data from a variety of electricity customers in line with the CLNR 2012 SDRC project milestone. To recap, the targets of the SDRC for December 2012 are as follows:

> *Provision of the following data sets for availability and use by other distributors and researchers:*
>
> - *Demand profiles grouped by customer type by end 2012;*
> - *Demand profiles grouped by low-carbon technology type by end 2012;*
> - *Demand profiles of existing generation types by end 2012.*
>
> *Evidence: data sets in an open and useable format issued to distributors and other interested parties.*

3.2 TC1a – Domestic electricity consumption

The profiles shown in this report show a high degree of similarity to those found in the ACE 49 report, the main distinction between the two datasets being the reduction in morning peak. Specific inter-sector analysis has not been carried out to date, however a preliminary analysis has found that of the average monthly peak demands, the rural samples (in particular rural-off gas participants) exceed the demands shown in the urban and suburban groups. Rural-off gas customers are likely to show greater electrical demand against rural-on gas customers due to electrical storage heating.

Maximum demand has been shown to typically occur in the winter months of December, January and February as expected, with the highest percentage of maximum demands found in December. Minimum demand was shown to occur in the period May 2011 to September 2011, with the highest percentage of minimum demands occurring in July.

Weekend and weekday profiles have been found to display somewhat different characteristics. Increased demand in the weekend lunchtime period can be likely attributed to greater occupancy against the weekday period. The early morning weekday peak is absent from the average profile, with the peak occurring much closer to 12:00. This peak is on average between 1.1 and 1.3 times the load seen during the weekday period on Saturday, and is between 1.3 and 1.5 times weekday load on Sunday. The presence of increased demand on Sunday when compared against Saturday and other days of the week give some credence to the inclusion of separate Sunday lunchtime loads within ACE 49.

Daily consumption has been analysed against the average weekday in order to quantify the variation in demand throughout the course of a week. A series of per-unit calculations and plots have shown that Monday and Friday appear to have somewhat different profiles to the average weekday with weekends predictably showing the largest difference.

3.3 TC1b – Small and Medium Enterprise consumption

Profiles have been derived for four main SIC classifications of SME trial participants. Significant differences are apparent between the sectors on aggregate, with further variations between flat-rate and multi-rate tariff profiles. Tariffs can therefore be concluded to have a definite effect upon the SME participants in this sample.

Multi-rate tariff customers all display an early morning peak, potentially attributable to electric storage heating (as per domestic customers). These customers also typically have higher demands than flat-rate customers, the exception being within the industrial sector.

Industrial customers show the most pronounced variation in electrical consumption, with roughly constant peak demand during the daytime period and minimal consumption outside of these hours.

Participants in the agricultural sector show little variation between weekday and weekend profiles with a distinct twin-peaked profile for multi-rate customers. The agricultural sector also shows the highest peak demand across the sample of all sectors. Profiles for the public sector and other category show little change in their shape between weekday and weekend, consumption is however reduced in the weekend period.

3.4 TC3 – Heat Pumps

The average 10-minute power consumption for a small number (<10) of heat pumps in August and September 2012 reveals what appear to be three distinct peaks in the electricity demand of these devices: at around 02.30, when an apparent defrost cycle runs and which is ~1kW on average and around 3.5kW peak; mid-afternoon (around 14.30); and during the evening peak demand period (around 18.30), which presumably coincides with the normal re-occupancy of domestic premises These profiles appear to be largely unaffected by the day of the week. The heat pumps in the study are all installed within the Northern Powergrid area but the specific locations, user demographics and models are not known at this time.

Subject to further study of a larger data set, in a central winter period, alongside correlation with temperature, this first view of heat pump demand profiles suggest that a single average heat pump demand curve may be adequate for representing this new network load, for inclusion in an updated ACE 49 standard. Of particular interest is that the night-time defrost peak would coincide with night-time EV charging peaks on the same network, and, as might be expected, heat pumps would add substantially to the evening (16.00-20.00) peak demand period.

3.5 TC5 / TC20a – Photovoltaics

The analysis of solar PV export for a small group of customers suggests that a single class of domestic PV generator could be used in network design. An informal inspection of the distribution of PV export power per 10-minute period shows that it is quite variable, with frequent positive skew and bimodal features. Individual generators show skew according to the orientation of the installation property (east /

west dominant facing) as expected, but in aggregate a group of generators displays a predictable export profile with a median of around 0.35-0.40 capacity factor and a small residual generation capacity at the 5th percentile. As the generators studied are distributed over a wide geographic area, further work will be needed to investigate the potential correlation at feeder level.

The question of whether PV owners' base load remains the same as that of a non-PV owner (i.e. do PV owners modify their electricity demand to take advantage of the "free" daytime electricity?) is still an open one and will depend on a more detailed analysis of additional household electricity monitoring, and a correlated investigation of social variables and attitudes for these customers, to inform an update to ACE 49.

3.6 TC6 – Electric Vehicles

Although only two electric vehicle customers were present in the study group it can be seen that the bulk of their charging was done in the evening and at night. Weekend and weekday charging was roughly in proportion to the relative durations of weekend and weekday periods as a proportion of the week. For much of the time, for both customers, the start times of charging episodes were so regular (at 19.00 and 20.30) that the use of timers is suggested. EV1 experiences a large frequency of charging at 19.00, often for a very short period of time (10-20 minutes) which suggests that the vehicle might be left permanently plugged in and is experiencing a top-up charge at the same time every day. Whatever the cause, this vehicle is imposing a significant load on the network during the early evening peak on a regular basis, albeit often for a short duration. EV2 is charged mostly during the late evening and during the night. EV1 driver charges regularly and has a considerable day-time demand, while EV2 driver charges infrequently and nearly always at night, the charging patterns for both EVs suggesting that neither is on a time-of-use tariff.

Interestingly, although there are only two vehicle charging patterns to look at, and although the trial run length is short, it is clear that the two EV owners exhibit different patterns of EV usage behaviour, and linking up studies of the metering data with analysis of social variables and tariffs will be important to understand this variability. Because EV charging demand is basically binary, an average load curve for a customer or a group is unlikely to provide a sensible model of load; a frequency model, perhaps related to occupancy, is likely to give better results, and the project will study such models as more data become available from the trials.

3.7 TC8 – Distributed generation profiles

The concept of a generation profile has been investigated with results shown for a variety of generation types. Profiles have been presented for wind turbines, landfill generation, hydro generation and a number of cogeneration sites.

Wind generation shows a typical output across the course of an average day as does landfill generation. The concept of a typical generation profile for these groups appears plausible. However, low capacity factors are an indication of output spikes, where an average has been taken across a large dataset. An analysis of the distribution of output across all customers is needed to investigate the contribution that these generators can make to network security. Seasonal variations in capacity factor will also be investigated to further examine the diurnal pattern throughout the course of a year.

Few comments can be made on a generation profile for hydro sites. An almost constant capacity factor has been observed for the sites in the sample, however the range of values and the highly limited number of sites means few conclusions can be drawn.

Landfill generation shows a distinct average profile, however within week variations are apparent. On average, capacity factors are reduced during the hours of 08:00 to 15:00 during the weekday period. Almost constant capacity factors are observed on average for the weekend period, with a smaller reduction in capacity factor between 09:00 and 11:00. Again, as for wind generation, a wide variation in capacity factors is present indicating that analysis of the distribution across all customers in the sample is needed.

Similarities have been observed within clusters of cogen site classifications, leading to the preliminary conclusion that a series of cogeneration profiles can be developed. A series of interviews with cogen customers will be pursued to greater understand this incredibly broad field of generation. Knowledge of business practices in how on-site generation is used will be important in assessing the nature of cogen profiles.

3.8 Final Summary

This report details the initial findings of analysis of metering data from a variety of electricity customers in line with the CLNR 2012 SDRC project milestone. To recap, the targets of the SDRC for December 2012 are as follows:

> *Provision of the following data sets for availability and use by other distributors and researchers:*
>
> - *Demand profiles grouped by customer type by end 2012;*
> - *Demand profiles grouped by low-carbon technology type by end 2012;*
> - *Demand profiles of existing generation types by end 2012.*
>
> *Evidence: data sets in an open and useable format issued to distributors and other interested parties.*

The data collected are from two sources. Test Cells 1a, 1b, 3, 5, 6 and 20a are provided by British Gas; test cell 1 data is half-hourly total energy (kWh) from smart meters, while the low-carbon technology test cells are monitored as 10-minute average power (W) from a bespoke solution produced for the CLNR project. Test Cell 8 data is provided by Northern Powergrid from mandatorily-metered generation sites. The datasets for low-carbon technology are limited as these trials are still in the initiation phase. The datasets for all test cells with the exception of TC8 are incomplete at present as the CLNR trials are on-going.

A series of domestic and SME demand profiles have been generated; these are partitioned by broad customer demographic classification (Urban, Suburban, Rural On-Gas and Rural Off-Gas), and by aggregated SIC classification (Agricultural, Industrial, Office/Commercial and Public Sector/Other) respectively. These profiles consist of average half-hourly real power consumption grouped by month, weekday and weekend periods, per customer type and classification.

Distributed generation profiles have been created for wind farms, landfill gas sites, hydro plant and various cogeneration schemes. Half-hourly capacity factors have been calculated in order to form generation profiles per site within each sector. Where necessary, customers have been sub-classified for further investigation.

Part of the aim of test cells 1a and 1b is to inform an update to the existing planning standard for LV network design, ACE49. The load profiles within ACE49 date from the late 1970s, and there is a requirement within the CLNR project to examine modern electrical consumption patterns with respect to these older profiles, and to propose appropriate modifications to the standard as a result. ACE49 also categorises load profiles based on both consumption and the presence of specific electrical appliances. These trials aim to quantify if these classifications are still relevant with current demand, and to infer new classes where necessary. The work outlined in this report details a preparatory summary of the data collected to date on the trials, to inform future studies in this area. More detailed information regarding the classification of SMEs in particular is required for future work.

The low-carbon technologies studied (PV, EVs, heat pumps) represent new electrical loads and generators that are not represented within ACE49 and which are likely to become a very large burden on the electrical network in coming decades. Analysis of these data will inform the creation of new profile classes for ACE49, and, as for test cell 1, the work conducted for this report represents preparatory analysis which will inform further studies leading.

The main output of Test Cell 8 is to provide generation profiles to update the Engineering Technical Report, ETR130. The concept of a generation profile is in general not well defined. Half-hourly capacity factors have been produced in a similar manner to the derivation of load profiles for domestic and SME customers.

Further analysis will include investigation of seasonality within profiles, with specific regard to wind farms and their diurnal profile shape. Landfill generation has been shown to display a typical profile; however the wide range of capacity factors infers that analysis of the distribution of output across all generators in the sample is required, in order to estimate the contribution to security of supply with confidence.

4 Acknowledgements

Although data organisation, analysis and report writing was carried out at Durham University, the production of this report has been a team effort involving a great many people from the CLNR project partners. Naturally the existence of the data itself is a result of funding provided through Ofgem's LCNF, and British Gas and Northern Powergrid have been responsible for delivering the customer data to be analysed. The following members of the CLNR team have also contributed substantially to the work herein by their action or support, and have made the production of this report possible:

British Gas: Allan Row, Cara Belady, John Bryce, Kevin Henry, Stavros Sachinis

Northern Powergrid: Andrew Spencer, Chris Thompson, David Miller, Glen Hodges, James Fletcher, Preston Foster, Stuart Brown

Durham Energy Institute: Chris Dent, Lorna Bang, Pádraig Lyons, Phil Taylor, Rukiya Sood

5 Appendix A – TC1b Aggregated SME Categories

This table is reproduced from Table 3 in the CLNR document "DEI-CLNR-RE022-TestCellsSMEProtocolForSelection-V1.1.doc".

<table>
<tr><th rowspan="2">Aggregated categories for the test cell selection</th><th rowspan="2">UK Standard Industrial Classification 2007 Categories</th><th colspan="2">UK Standard Industrial Classification 2003 Code</th></tr>
<tr><th>Letter Code</th><th>4 digit Numeric Code</th></tr>
<tr><td>Agriculture, Hunting and Forestry; Fishing</td><td>Agriculture, Hunting and Forestry; Fishing</td><td>A, B</td><td>0100-0502</td></tr>
<tr><td rowspan="3">Industrial</td><td>Mining and Quarrying; Electricity, Gas and Water Supply</td><td rowspan="3">C, D, E, F</td><td rowspan="3">1000-4550</td></tr>
<tr><td>Manufacturing</td></tr>
<tr><td>Construction</td></tr>
<tr><td rowspan="5">Commercial/Office</td><td>Wholesale and Retail Trade; Repairs</td><td rowspan="5">G, H, I, J, K, and some of O</td><td rowspan="5">5000-7489, 9260-9309</td></tr>
<tr><td>Hotels and Restaurants</td></tr>
<tr><td>Transport, Storage and Communication</td></tr>
<tr><td>Financial Intermediation</td></tr>
<tr><td>Real Estate, Renting and Business Activities</td></tr>
<tr><td rowspan="3">Public Sector and Other</td><td>Education</td><td rowspan="3">L, M, N, and some of O</td><td rowspan="3">7500-9253</td></tr>
<tr><td>Health and Social work</td></tr>
<tr><td>Other Community, Social and Personal Service Activities</td></tr>
</table>

Table 7 - Aggregated SME Sector Categories by SIC 2007 Categories and SIC 2003 Code

6 Appendix B – Datasets

Excel files containing load and generation profiles data accompanying this report are described below.

CLNR-SDRC-Dec2012-LCT-Profiles-V2

TC3 HP AUG Averages: average demand profile per 10-minute sample period in W for 5 heat pumps for Aug 2012, by day, weekend / weekday, and total.

TC3 HP SEP Averages: average demand profile per 10-minute sample period in W for 8 heat pumps for Sep 2012, by day, weekend / weekday, and total.

TC5 PV CF JUL Group: group PV capacity factors for 11 customers in aggregate (5/50/95%) in Jul 2012, daily + month, all arrays operating that month.

TC5 PV CF AUG Group: group PV capacity factors for 30 customers in aggregate (5/50/95%) in Aug 2012, daily + month, all arrays operating that month.

TC5 PV CF SEP Group: group PV capacity factors for 83 customers in aggregate (5/50/95%) in Sep 2012, daily + month, all arrays operating that month.

CLNR-SDRC-Dec2012-TC1a-Profiles-Dataset

Monthly average consumption in kW per half hour for all customers per sector (Urban, Rural on gas, Rural off gas and Suburban). Average consumption for individual week days and each day of the week as a per-unit value of the average weekday consumption for each individual month.

CLNR-SDRC-Dec2012-TC1b-Profiles-Dataset

Monthly average consumption in kW per half hour per sector (Agricultural, Industrial, Office and Commercial, Public Sector and Other) for aggregate sector, flat-rate and multi-rate customers. Average consumption for individual week days and each day of the week as a per-unit value of the average weekday consumption for each individual month.

CLNR-SDRC-Dec2012-TC1-Daily-Means-kWh

Daily mean energy consumed by all customers in the noted class for that day. Recorded values are demand by half-hour, in kWh recorded over the previous half-hour. Classes correspond to the test cell selection classes presented in the load profile analysis in sections 2.2 and 2.3, i.e. Residential (TC1a): Rural Off-Gas; Rural On-Gas; Suburban; Urban: and SME (TC1b): Agricultural; Industrial; Office / Commercial; Public Sector / Other. SME categories are also further categorised by tariff type, i.e. flat rate or multi-rate.

CLNR-SDRC-Dec2012-TC8-Profiles-Dataset

Monthly average consumption in kW per half hour for all sites (Wind, Landfill, Hydro, and Cogeneration). Average consumption for individual week days and each day of the week as a per-unit value of the average weekday consumption for each individual month where necessary (Landfill and Cogeneration).