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Final Report:

The impact of changing energy use patterns in buildings on peak electricity demand in the UK

Prepared for: Hunter Danskin
DECC

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DEPARTMENT OF ENERGY & CLIMATE CHANGE

Prepared by

Name Christine Pout, Fiona MacKenzie and Elena Olloqui

Position Sustainable Energy Group

Signature

Approved on behalf of BRE

Name Paul Davidson

Position Director, Sustainable Energy Group

Date

Signature

BRE
Garston
WD25 9XX
T + 44 (0) 1923 664000
F + 44 (0) 1923 664010
E enquiries@bre.co.uk
www.bre.co.uk

Executive Summary

This study provides an improved understanding of the end use components of peak demand electricity in the UK so that the potential for reducing peak demand through improved energy efficiency in the building stock can be assessed. It builds on earlier work[1] and draws in additional data sources to provide an enhanced understanding of the end use components that make up peak electricity demand. To capture the impact of change over the course of a year, the model considers the daily demand profile for the day in which peak demand occurred (in 2006), in each quarter. This showed that lighting, catering, consumer electronics and, in the summer quarters cooling, are the building end uses where there is likely to be the most potential for demand reduction.

A spreadsheet model was developed to consider how changes in end use demand and technological changes are expected to alter electricity demand in future years. A "business as usual" scenario was constructed to explore how changes in energy service demand and technological efficiency might affect the size of peak demand and where it occurs during the course of the day, and in which quarter. For buildings, which account for 66% of total electricity demand, this was based on the policy scenarios for domestic and non-domestic buildings which were previously developed for DEFRA[2] and which include the anticipated effect of relevant policies which appeared in the Energy White Paper[3].

This "business as usual" scenario (which assumes improvements in energy efficiency) showed that in the winter quarters (Q1 and Q4) peak demand will fall slightly to 2030, but then rise again so that by 2050 peak demand will be a few percentage points higher than it currently is, with only minor changes to the shape of the daily demand profile. Whereas in Q2 and Q3 a significant increase in daytime demand is expected, primarily due to increased demand for cooling and computers and consumer electronics, so that by 2050 summer peak demand is close to the winter peak.

Other scenarios were developed to look at the impact of increased levels on onsite electricity generation, wider deployment of heat pumps and different demands for cooling. The renewable generation scenarios indicate that, even when significant levels of onsite renewable electricity generation are deployed, although they may lead to a noticeable reduction in the annual demand, they do not necessarily impact on peak demand. The modelling also showed that if heat pumps increasingly replace boilers for providing space heating and hot water, then peak demand could increase significantly. Similarly, if demand for space cooling increases faster than anticipated then peak demand could shift to Q2 and Q3. Other scenarios that were modelled were: a zero carbon new build scenario, which represents the levels of onsite electricity generation and heat pumps that a zero carbon new build policy might prompt; a scenario which looks at the combined impact of the onsite wind, onsite PV and heat pumps;, and a scenario where the increase in cooling demand is limited. The results of the scenario modelling for 2050 is summarised in the following table.

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[1] Potential for Reducing Peak Electricity Demand from Buildings, BRE report for DEFRA, March 2006

[2] Possible Scenarios for Future Domestic Energy Use and Carbon Emissions to 2050, BRE report for DEFRA, December 2004
Reducing Carbon Emissions for Commercial and Public Sector Buildings in the UK, BRE report for DEFRA, January 2005

[3] Meeting the Energy Challenge: A White Paper on Energy, May 2007, DTI.

Scenario	Peak Demand		Annual GWh
	GW	% Change	% Change
"Business as Usual"	60.76	-	-
Onsite Wind Generation	59.1	-3%	-3%
Onsite PV Generation	60.76	-	-9%
Heat Pumps	62.08	2%	2%
High Growth Cooling	72.95	20%	9%
Zero Carbon New Build	60.54	-0.4%	-3%
Onsite Generation and Heat Pumps	60.01	-1%	-10%
Limit Cooing	60.76	-	-3%

These scenarios indicate that, aside from the impact of increased cooling, the effect of technology change on peak electricity demand is relatively small.

The report also identifies additional data sources that could be used to improve the current model of electricity demand, and makes recommendations for further work.

Contents

1 Introduction

This report is the final deliverable of a research project for DEFRA (now DECC) entitled “The impact of changing energy use patterns in buildings on peak electricity demand in the UK”.

The overall aims of the project are to update the results of an earlier study[1] to take account of more up to date demand profiles and draw on additional studies which relate to end use demand. This requires an improved understanding of the annual electricity demand profile for grid supply power, disaggregated by sector and end use. This then forms a basis for developing a spreadsheet model that can be used to consider how changes in end use demand and the technologies used to meet this demand will impact on peak demand, (including where and when peak demand is expected). The model can then be used to assess the effect changing patterns in end use demand in domestic and non-domestic buildings. The changes that are explored here include;

- improving energy efficiency in existing technologies and of new and emerging technologies (which will affect both peak demand and the remaining potential for reduction),
- alternative technologies that involve fuel switching, e.g., heat pumps replacing condensing boilers
- on site electricity generation (from wind, PV, CHP and micro CHP), and
- climate change induced weather patterns on the end use demand for cooling and heating.

The specific objectives of the project are to:

- Determine the end uses of energy in buildings and their contribution to the current electricity demand over the course of a year.
- Assess the extent to which energy use in buildings currently contributes to peak demand for electricity.
- Consider how changes in end use demand and technologies are expected to alter electricity demand in future years.
- Assess the extent to which peak electricity demand from buildings can be reduced through improved energy efficiency.
- Identify information gaps and propose how missing data might be obtained.

2 Background

In the UK, electricity consumption is responsible for around half of the total carbon dioxide emissions arising from energy use, and the vast majority of this energy is used in buildings for space conditioning (heating, lighting etc) and by equipment and appliances (ranging from PCs through to energy intensive industrial processes). In contrast to fossil fuel consumption, the demand for electricity has continued to increase over past decades and could continue to rise in future years if significant steps are not taken to reverse this trend. As well as increasing the overall amount of carbon dioxide and other greenhouse gas emissions, increasing demand for electricity will require additional electricity generation capacity to be built, particularly as decommissioning of the majority of nuclear stations by 2020 might substantially reduce the generation capacity. Reducing demand for electricity, particularly peak demand is, therefore, a particular concern.

The work follows on from an earlier study titled “Potential for Reducing Peak Electricity Demand from Buildings” which was carried out on behalf of DEFRA in 2006. This short study estimated the contribution that end uses of energy in domestic and non-domestic buildings make towards the load profile for a winter weekday of peak demand and estimated that implementing all cost effective energy efficiency measures in buildings would lead to a 9GW reduction in peak demand, around 10% of the total GB demand. This previous study was based on daily demand profiles for 2004/05 and the end use demand profiles were built up from readily available sources.

3 Electricity Consumption Patterns in the UK

This section identifies data relating to the current demand for grid electricity supplied in Great Britain and how it varies over the course of a year, and to other information relating to electricity demand at the sectoral and end use level, with a particular emphasis on building related electricity.

3.1 Sectoral Breakdown of Electricity Consumption

In order to assess where the demand for electricity is coming from at a sectoral level within the UK economy, BERR DUKES[2] data has been used. These data provide a sectoral breakdown of final use electricity demand. The total electricity produced for the public supply system in 2006 was 405,044 GWh,. Around 7% of this was attributable to transmission losses (most of which was distribution losses occurring between the gateways to the public supply system's network and the customer's meters), thus the total demand for electricity in the UK in 2006 was 374,846 GWh. From Figure 1 below it is clear that whilst industry is a large consumer of electricity, buildings (domestic, commercial and public administration) accounted for over 50% of total UK electricity demand in 2006.

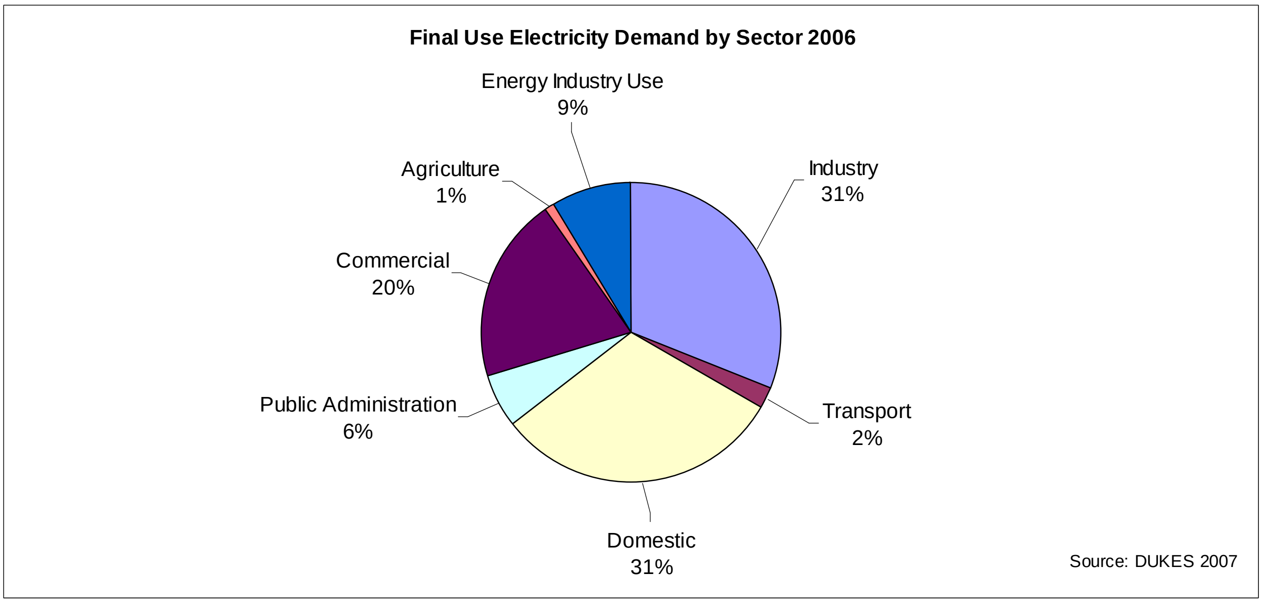

Figure 1: Electricity demand by sector (2006)

There will also be some building conditioning energy use in industrial buildings, but this has not been explicitly considered here.

3.2 Electricity Consumption in Buildings by End Use

To take the assessment of demand for electricity to a more detailed level it is necessary to look at where this demand is coming from within the buildings themselves. Electricity consumption by end use in 2005 is based on BRE housing data published in a BERR report[3]. This data amalgamates lights and appliances and the split has been made based on ECI data[4] which estimates that 25% of this is attributable to lighting and the remainder to appliances. Figure 2 shows the breakdown of electricity demand by end use for the domestic sector.

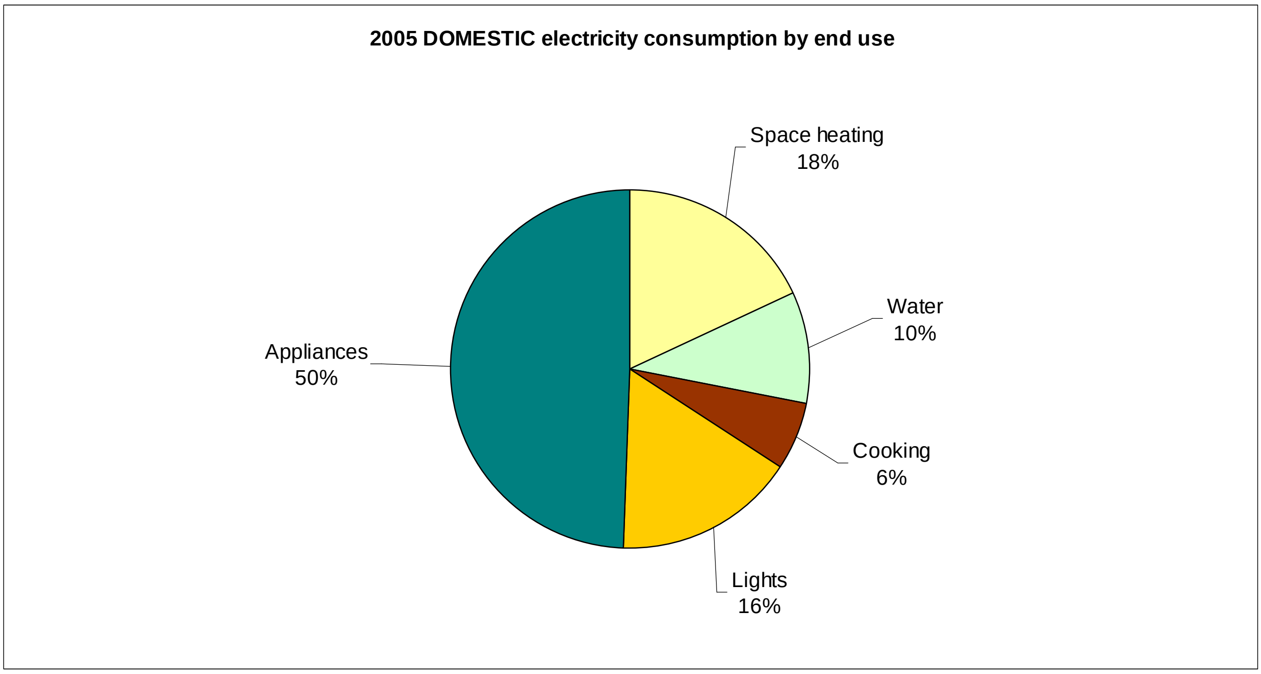

Figure 2: Domestic electricity consumption broken down by end use (2005)

Similarly, Figure 3 shows the break down of electricity consumption by end use in the non-domestic sector. This data is based on figures from the Non-Domestic building Energy and Efficiency Model (N-DEEM) for 2006.

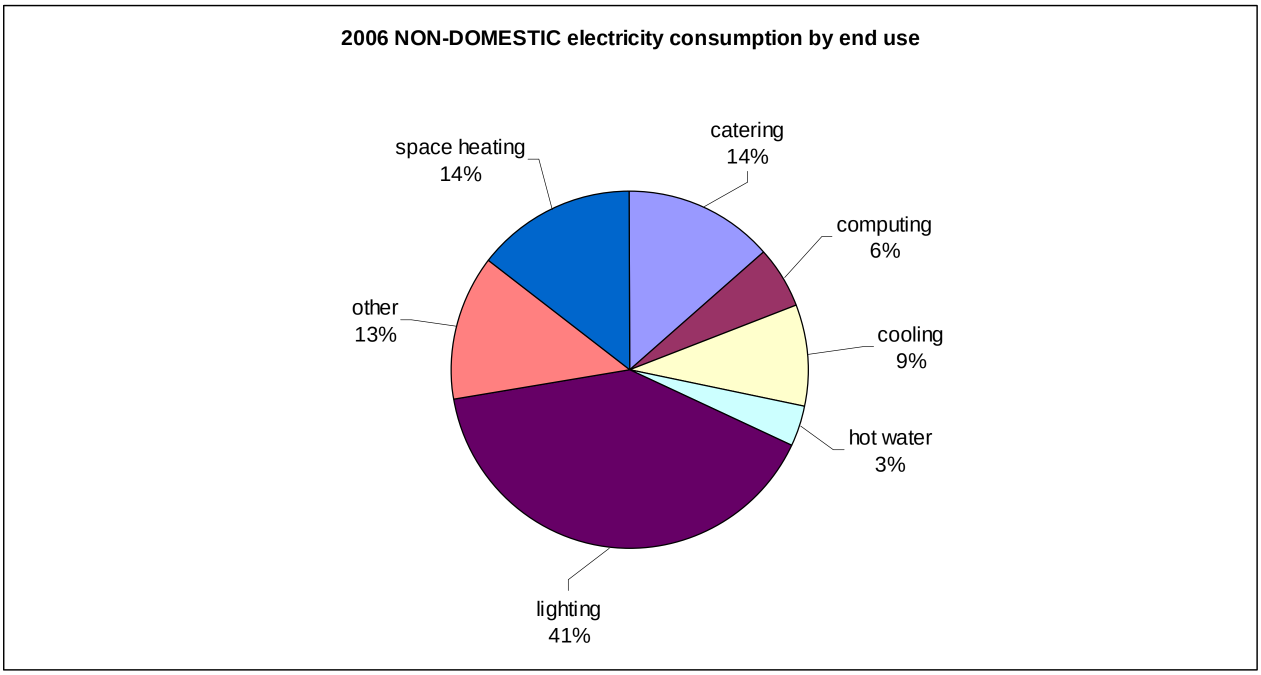

Figure 3: Non-domestic electricity consumption broken down by end use (2006)

4 Grid Supply Electricity in Great Britain

The latest daily half hourly electricity demand data from the National Grid[5, 6] provide annual actual consumption values to which the sectoral and end use estimates must be reconciled. Here, data for 2006 have been used since this is the latest year for which other comparable information is available. For the purpose of this study we have assumed that the electricity consumption pattern in Northern Ireland is the same as for the UK. Although Northern Ireland only accounts for around 3% of overall energy demand, because of the absence of a mains gas grid in the past, the fuel consumption patterns (and the electricity generation mix) are known to be considerably different from those of Great Britain. Further work would be needed in order to provide a more robust assessment of electricity demand in Northern Ireland.

Analysis of this data allows an assessment of average daily demand profiles, how these differ on weekdays compared to weekends/holidays, seasonal variations in electricity demand and identification of peak demand days.

Historical electricity demand data for Great Britain is now available from the National Grid website and gives half hourly demand for each day going back to 2001. As a first step we analysed this data to determine;

- whether there are any obvious anomalous peak days which are unrepresentative and which would provide an inappropriate basis for modelling, and
- if there were any discernable trends in the daily demand profiles over recent years.

4.1 Electricity Demand Profiles 2002 to 2008

The following charts show the day of peak electricity demand that occurred in each quarter[d].

[d] Where Q1=January to March, Q2 = April to May, Q3=July to September and Q4=October to December.

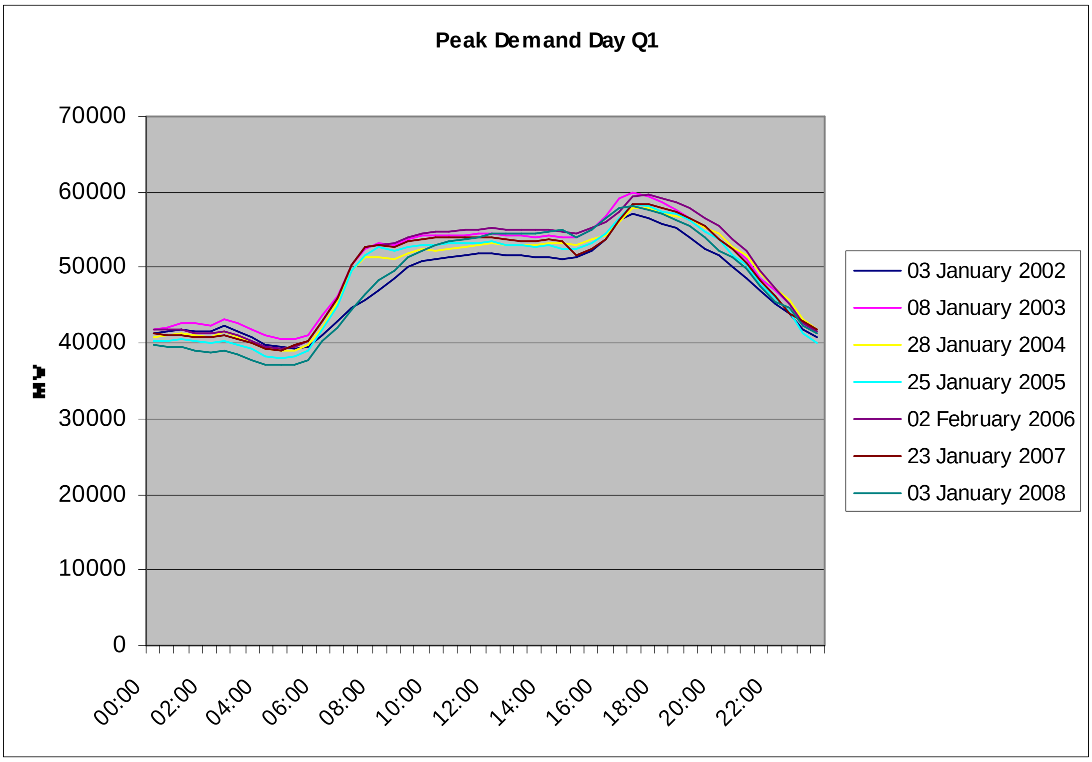

Figure 4: GB Electricity Demand Profiles for the Day of Peak Demand in Quarter 1

NB: The slower increase in demand observed on the morning of 3rd January 2002 and again in 2008 is almost certainly due to the fact that it fell at the end of the Christmas holiday period.

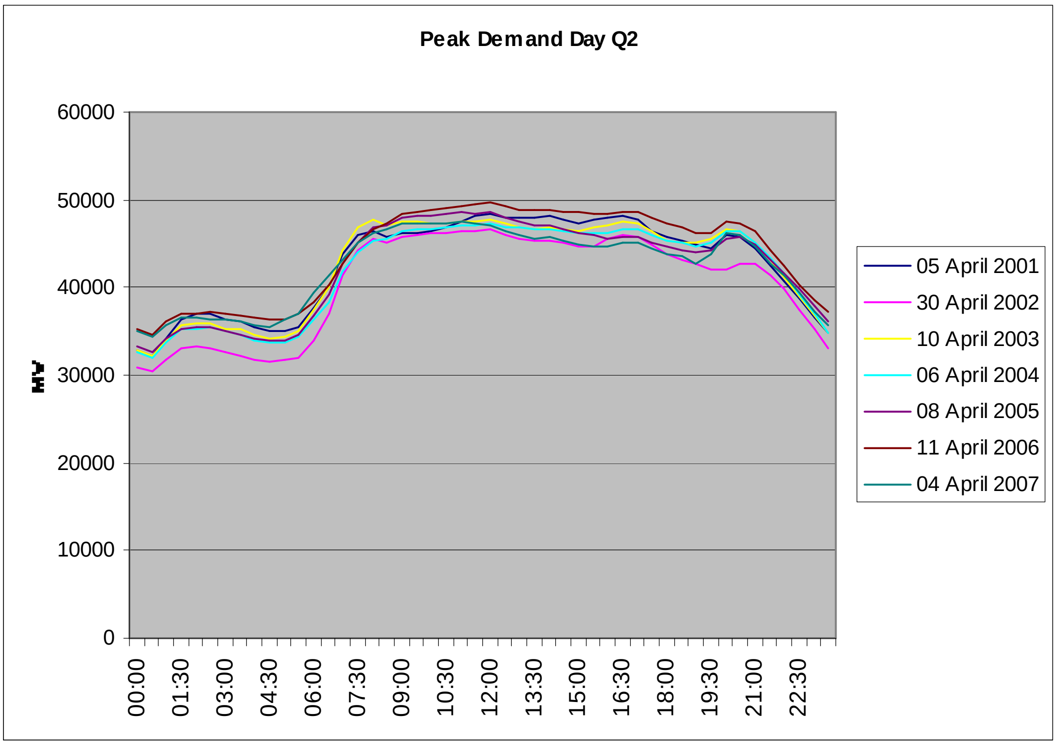

Figure 5: GB Electricity Demand Profiles for the Day of Peak Demand in Quarter 2

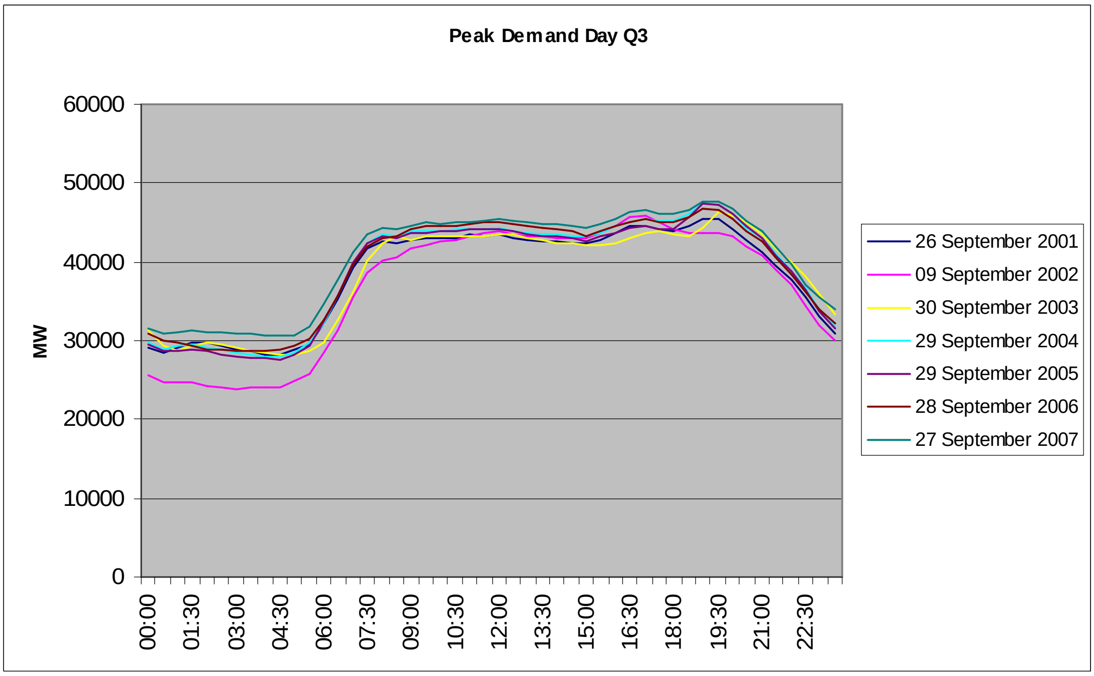

Figure 6: GB Electricity Demand Profiles for the Day of Peak Demand in Quarter 3

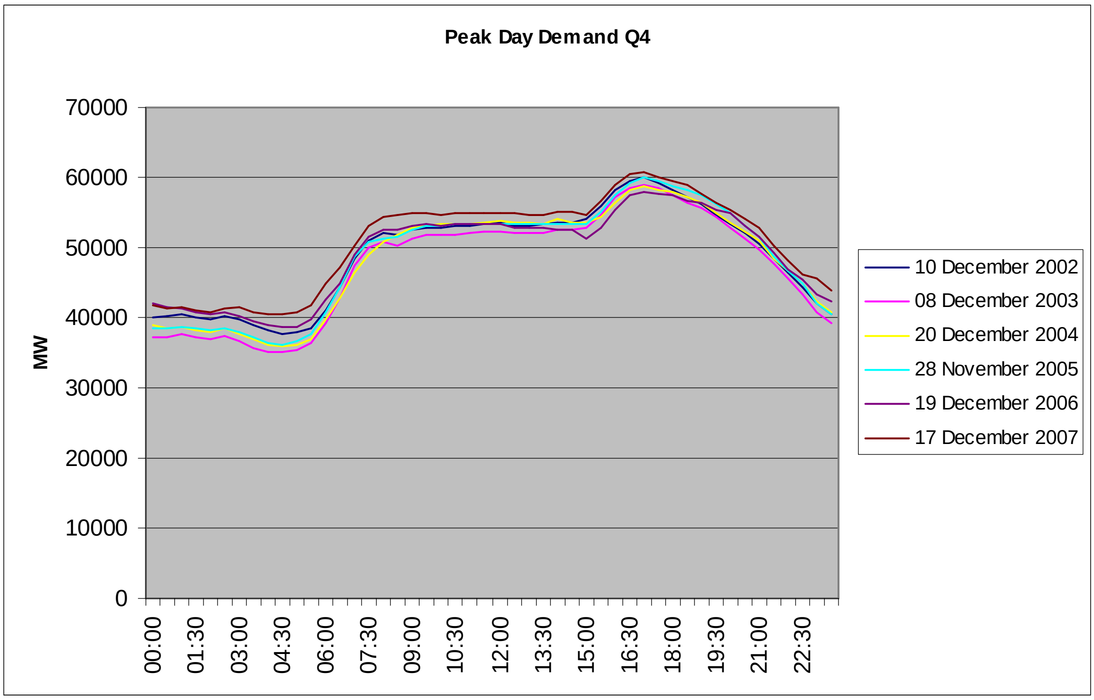

Figure 7: GB Electricity Demand Profiles for the Day of Peak Demand in Quarter 4

In each quarter the peak demand day fell on a weekday, and most often on a Monday, possibly because over the weekend many business premises will be unoccupied, so there will be less residual heat in the building. No obvious trends in terms of the height and position of peak demand are apparent. So we concluded that data for four quarterly peak demand days for 2005/2006 would form a suitable basis for modelling.

4.1.1 Current Electricity Demand Profiles

From the analysis of the National Grid data, revised electricity demand profiles have been constructed as shown in Figures 8 to 10 below which depict the annual demand profiles split into weekdays and weekends/holiday, and also split into winter and summer demand. These show the profile for the peak electricity demand day in 2006 as well as the peak summer electricity demand day.

These charts show that weekday demand is higher than weekend/holiday demand and winter demand is higher than summer demand[e]. Overall, on average the peak demand occurs at 18:00 hours and is 45.0GW; however, this increases to 53.4GW in winter also at 18:00 hours and decreases to 39.6GW in summer and peaks much earlier in the day at 16:00 hours. These differences are clearly a reflection of the requirements for electrical equipment, lights and appliances. It is likely that the earlier peak in summer is due to air conditioning requirements and the later peak in winter due to heating and lighting requirements and in turn, these requirements are essentially brought about by changes in temperature and daylight hours.

Over the course of the average day, the difference between peak demand (45.0GW at 18:00 hours) and the lowest demand (29.6GW at 04:30 hours) is 15.4GW.

On the peak demand day (a February weekday) the peak demand for electricity was 59.1GW at 18:00 hours. This was 14.1GW higher than the peak on an average day and 8.4GW higher than the peak on an average winter day. It is not surprising that the peak occurs in February since although on average since 1970 January is colder than February, in 2006 February was the coldest month of the year[2].

On the peak demand day during the summer (a July weekday) the peak demand for electricity was 44.1GW at 16:30 hours. This was 0.9GW lower than the peak on an average day and 4.5GW higher than the peak on an average summer day. Mean temperature data for 2006[2] shows that July was, unusually, considerably warmer (~3oC) than August in this year indicating that this peak may be at least in part related to temperature, with the possible implication that increased use of air conditioning has contributed to the peak summer demand.

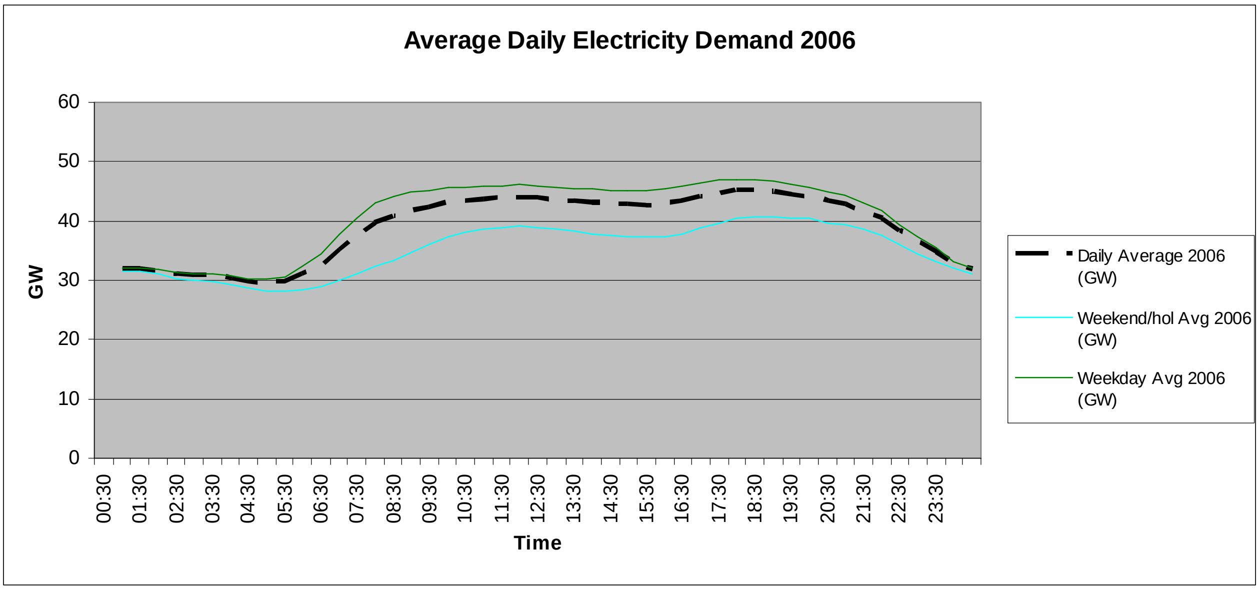

Figure 8: Average daily electricity demand in the UK (2006) split into weekdays and weekends/holidays

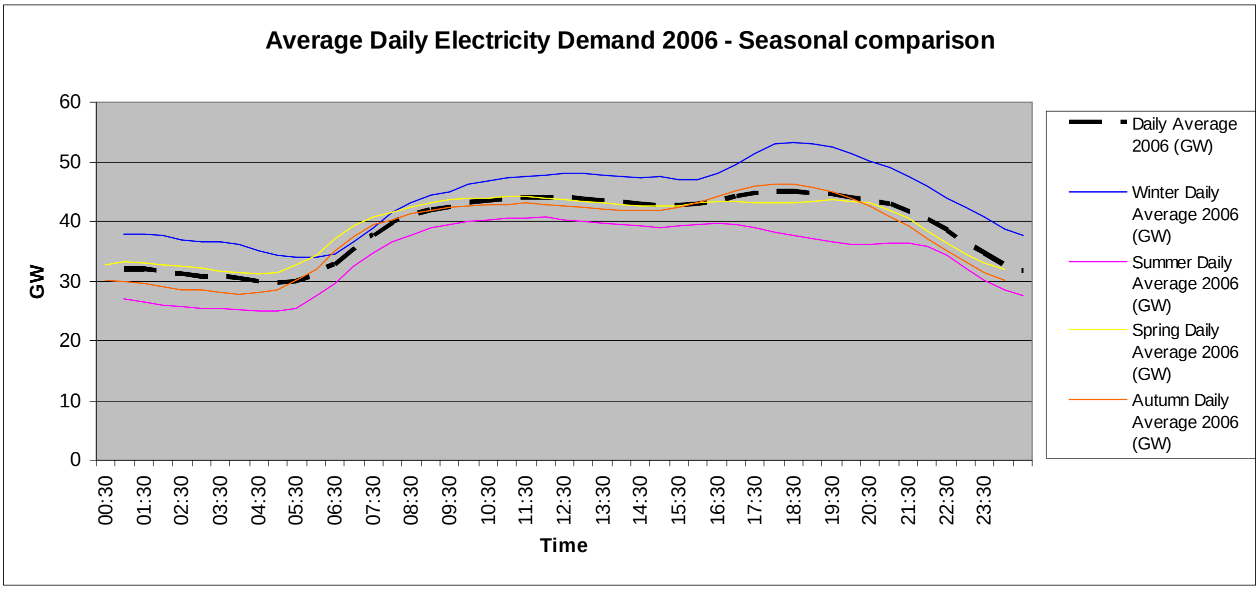

Figure 9: **Average daily electricity demand in the UK (2006) split into winter days and summer days**[e]

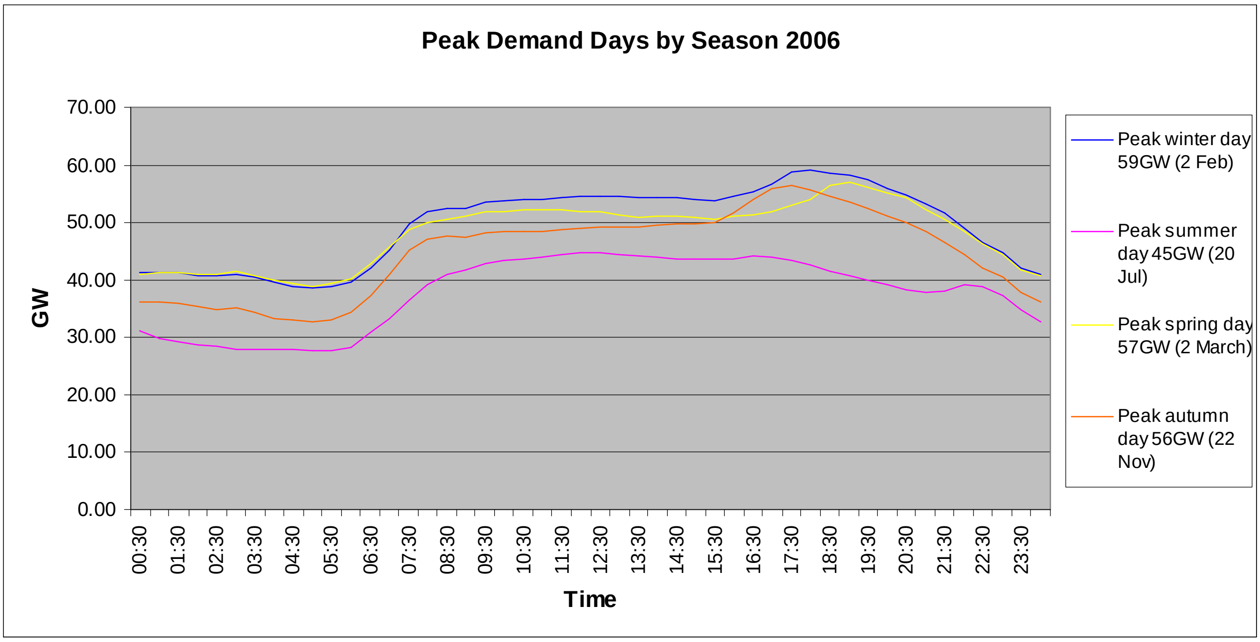

Figure 10: Peak demand days by season for 2006

[e] Winter is December, January, February; spring is March, April, May; summer is June, July, August and autumn is September, October, November.

4.2 Load Profiles by Sector and End Use

In order to identify the contribution that buildings and their end uses make to the peak demand, the load profiles for the peak quarterly[f] electricity demand days in 2006 have been taken and an attempt has been made to disaggregate the demand profiles by sector and by end use.

4.2.1 Sector Breakdown of Peak Demand Electricity

In order to determine how the various sectors contribute to the peak demand day it is first necessary to determine quarterly electricity consumption. BERR statistics[g] allow the quarterly energy demand to be determined for the following sectors; domestic, public and commercial buildings, energy industry use, other industry and agriculture, which is shown in the following chart. It can be seen that the quarterly variations in demand are greatest for the domestic and public and commercial buildings sectors; this is because the heating and lighting demand, which make up a significant proportion of the total, are strongly seasonal and show a strong correlation with external temperature and day length, respectively.

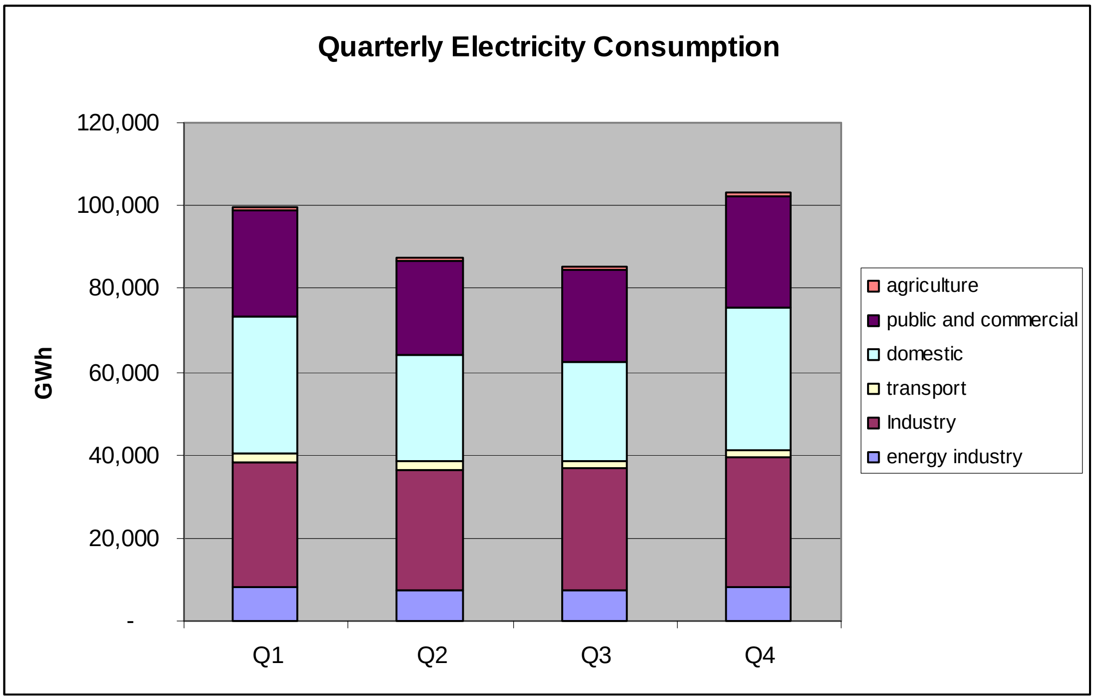

Figure 11: Sectoral Breakdown of Electricity Consumption in the UK 2006

[f] Quarterly data has been used for this part of the analysis rather than seasonal data which was used for the earlier part of the analysis. The reason for this is that the BERR statistics used in this analysis are on a quarterly basis. Quarterly data categorises the months as follows: Quarter 1 = January, February and March, Quarter 2 = April, May and June, Quarter 3 = July, August and September, Quarter 4 = October, November and December.

[g] BERR Energy Trends, http://www.berr.gov.uk/whatwedo/energy/statistics/publications/trends/index.html

To look at how this sectoral demand varied over the course of a day we looked to Exelon load profiling data which is based on sample customers belonging to different profile classes[h]. Where the profile classes are:

- Domestic unrestricted
- Domestic Economy 7
- Non-Domestic unrestricted
- Non-Domestic Economy 7
- Non-Domestic Maximum Demand with a peak load factor <20%
- Non-Domestic Maximum Demand with a peak load factor >20% <30%
- Non-Domestic Maximum Demand with a peak load factor >30% <40%
- Non-Domestic Maximum Demand with a peak load factor <40%

A domestic sector demand profile was derived based on the ratio of energy consumption by Economy 7 and other tariff domestic customers[i]. Similarly a profile for non-domestic energy consumption was generated assuming a similar mix of the non-domestic unrestricted and non-domestic Economy 7 profiles, whilst an average of the maximum demand profiles was taken to be representative of industrial process energy consumption. For street lighting it was assumed that peak demand would be twice the annual average (based on an average night length of 12 hours) and that on mid winters day they would be switched on at 16:00 in the afternoon and off at 8:00 in the morning. It was assumed that energy industry demand would be constant, as these are likely be operational 24 hours a day, and, in the absence of any additional information, the small demands associated with the agriculture and transport sectors were assumed to be constant as well.

The results of this sectoral profiling exercise are shown below:

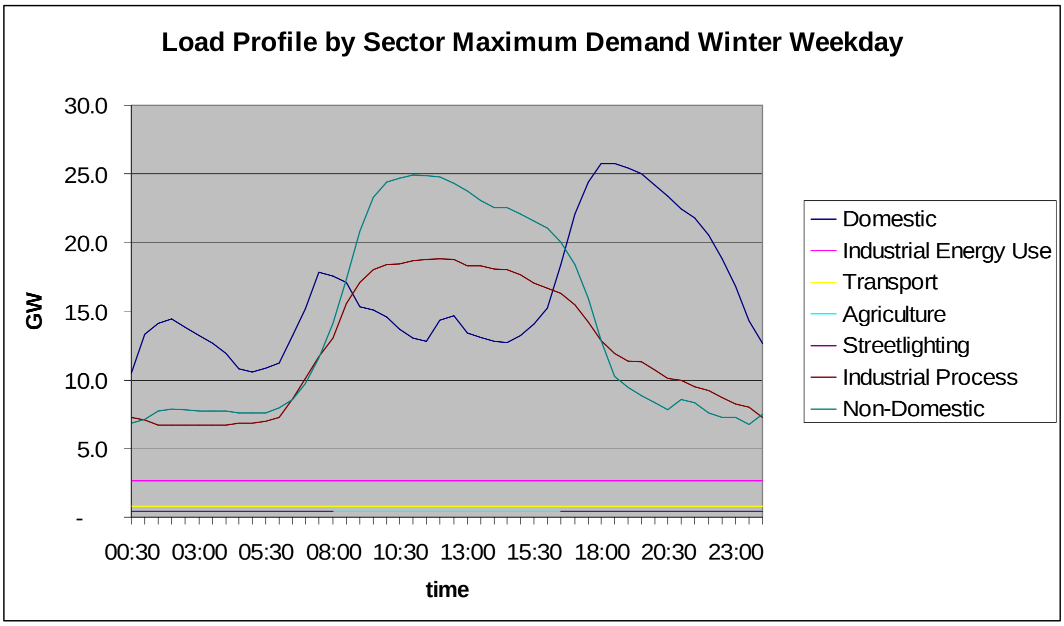

Figure 12: Sectoral Load Profiles Constructed from Profile Classes

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[h] Load profiles and their use in electricity settlement, Exelon,
[i] Digest of United Kingdom Energy Statistics 2007, BERR

These sectoral profiles were then reconciled to fit the actual demand profile for the peak demand day in Q1[j], where the reconciliation was carried out in two steps. Firstly the half hourly demand for each sector were adjusted, pro rata, to match the actual demand. Then, the revised sectoral profiles were adjusted so that the electricity consumption over the 24 hours matched that of the original sectoral demand (i.e, the sum of the sectoral areas shown in Figure 14 is equal to the sum of the equivalent areas in Figure 13)

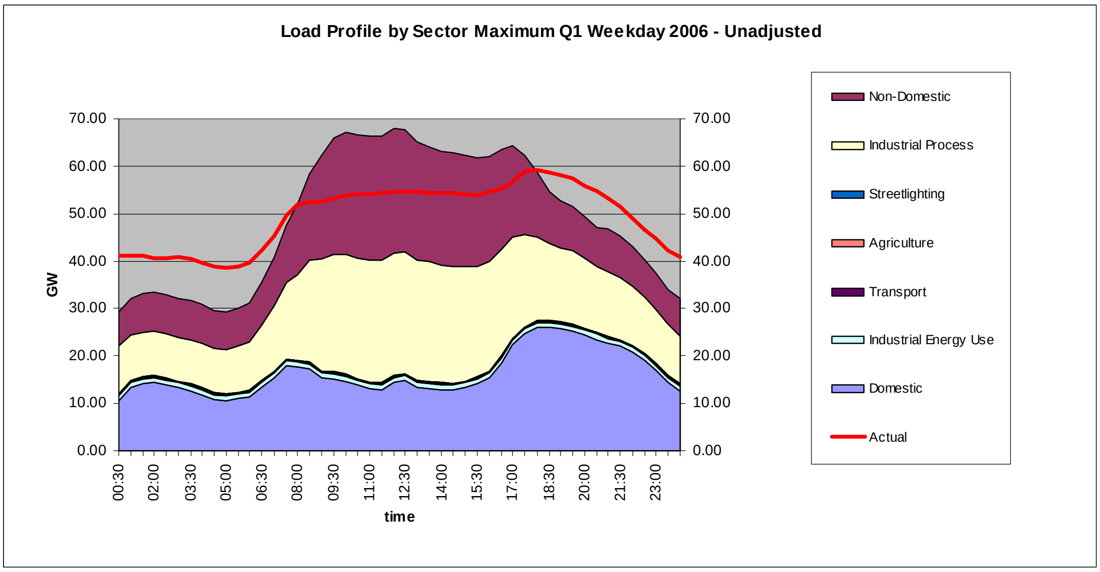

Figure 13: Sectoral Load Profiles Constructed from Profile Classes compared to the Actual Demand Profile for the Peak Day in Quarter 1

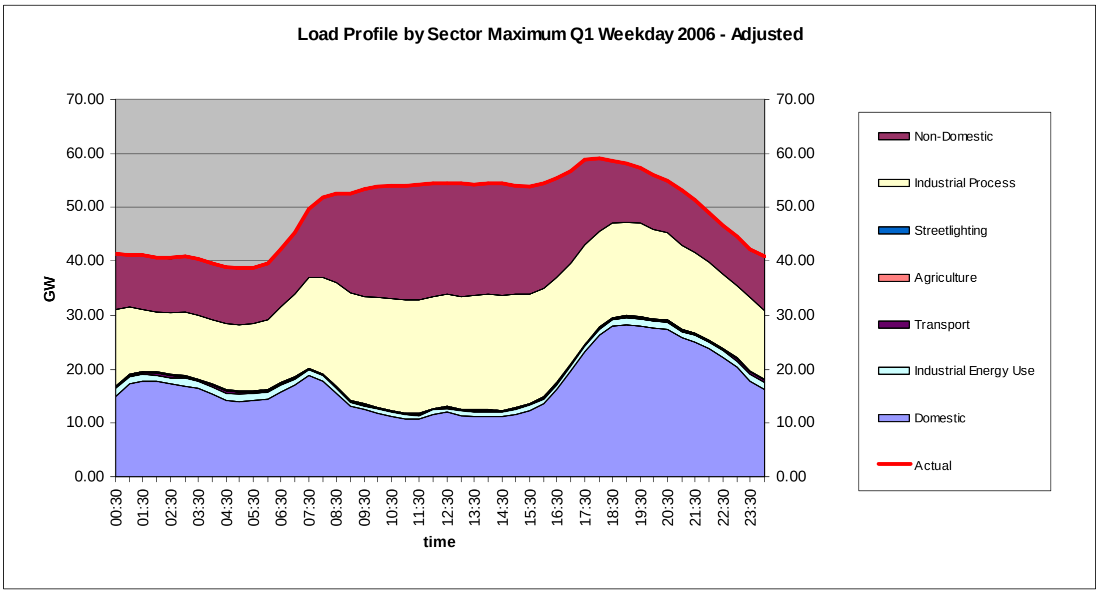

Figure 14: Sectoral Load Profiles Constructed from Profile Classes Adjusted to fit the Actual Demand Profile for the Peak Day in Quarter 1

[j] It is noticeable that night time demand in particular appears to be underestimated, although in part this can be attributed to poor control regimes with equipment and services being left on overnight.

The following charts show the electricity demand profiles for the peak demand days occurring in Q2, Q3 and Q4 broken down by sector produced in a similar way.

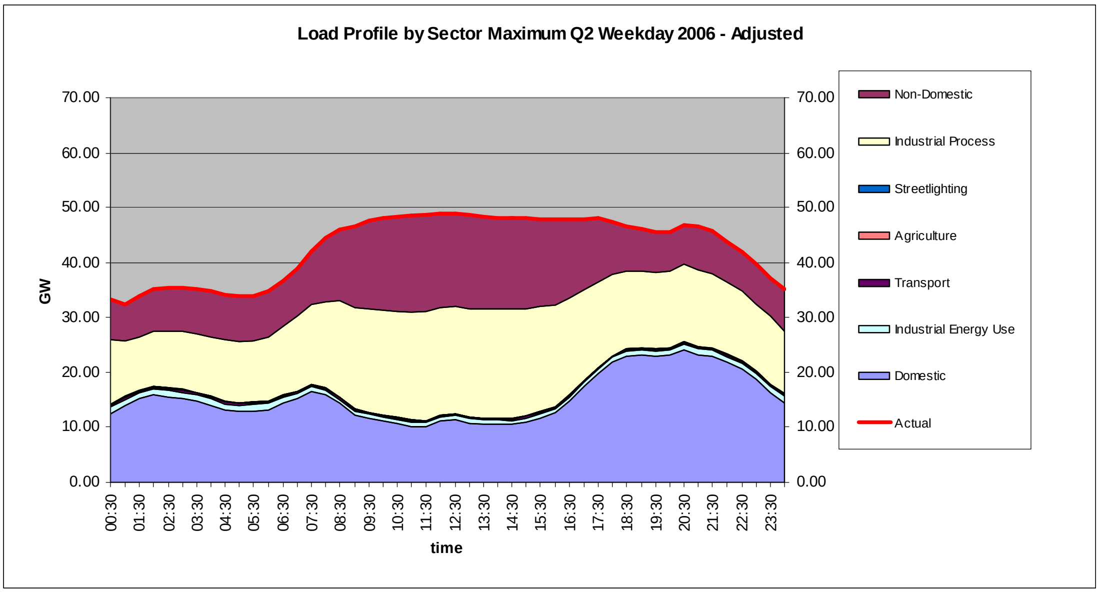

Figure 15: Sectoral Load Profiles Constructed from Profile Classes Adjusted to fit the Actual Demand Profile for the Peak Day in Quarter 2

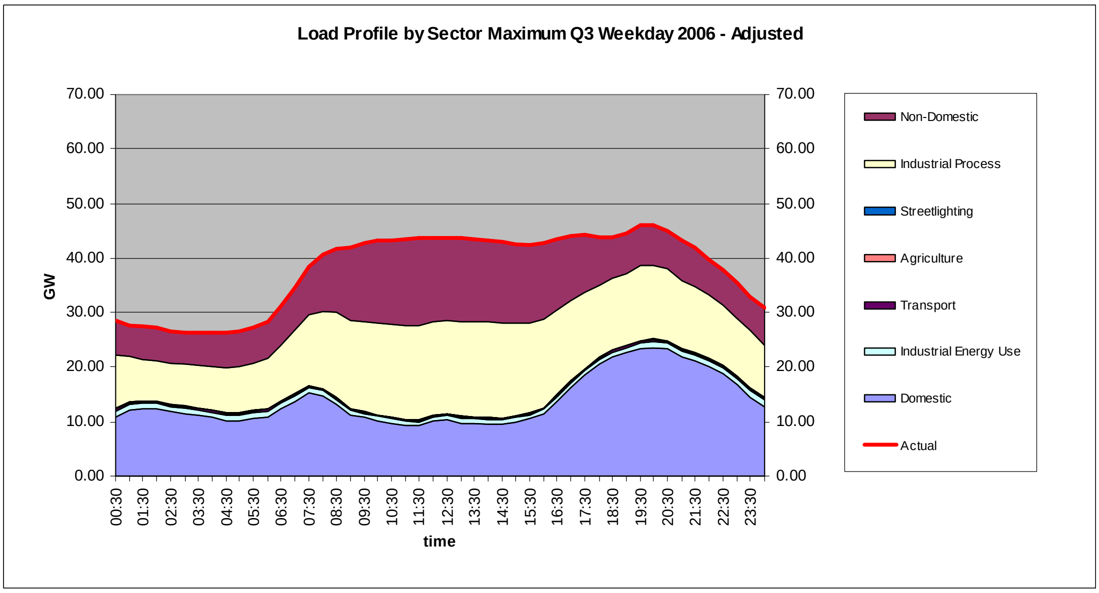

Figure 16: Sectoral Load Profiles Constructed from Profile Classes Adjusted to fit the Actual Demand Profile for the Peak Day in Quarter 3

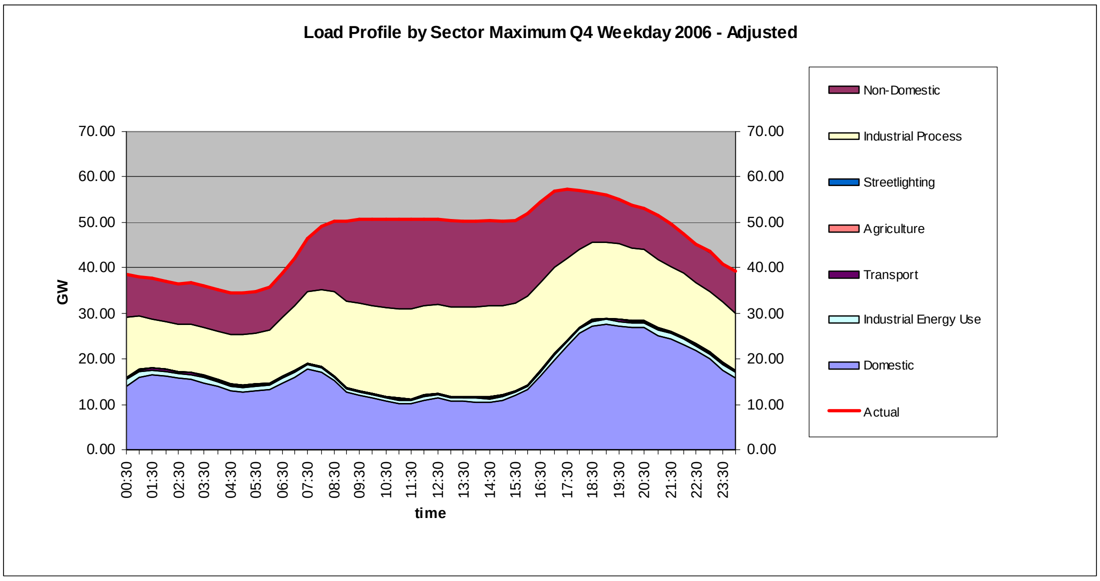

Figure 17: Sectoral Load Profiles Constructed from Profile Classes Adjusted to fit the Actual Demand Profile for the Peak Day in Quarter 4

The over-estimation of day time demand seems to be greater in the winter months compared to the summer months perhaps indicating that the issue could be related to heating consumption. This could be related to demand profiles for electric heating, but it would require further investigation before this could be proved Standby energy consumption by electronic appliances will clearly account for some of this night time demand, but recent studies indicated that the average demand from standby consumption are between 0.9 and 1.6 GW[k]. Unfortunately this is not something which we have been able to resolve since the previous piece of work on demand curves, as we have not been able to identify any updated data in this area.

Figure 18 below shows the (unadjusted) change in demand for each sector relative to each other. There is a small peak in domestic demand at around 07:30 hours as people prepare for work and school. The main peak in all quarters occurs at around 18:00 hours, mainly as a result of the peak in domestic demand due to people arriving home from work and school. Adding to this peak in domestic demand is the fact that non-domestic demand, although decreasing, is still not at its lowest point as many people are still at work. In quarters 2 and 3 the peaks are all lower mainly due to the decreased requirement for lighting. It is interesting to note that in these quarters industrial process demand does not decrease to the same extent as the domestic and non-domestic demand presumably as much of the electricity consumed in this sector is for the industrial processes themselves which are not generally affected by changes in lighting and heating requirements. Additionally it is interesting to note that there is no obvious peak in quarters 2 and 3 in the non-domestic sector at around 16:00 hours which is when one might expect air conditioning use to be at its peak. However, as air conditioning currently accounts for only a few % of the total demand this is probably not surprising.

[k] BNXS36: Estimated UK standby electricity consumption in 2006, http/www.mtprog.com

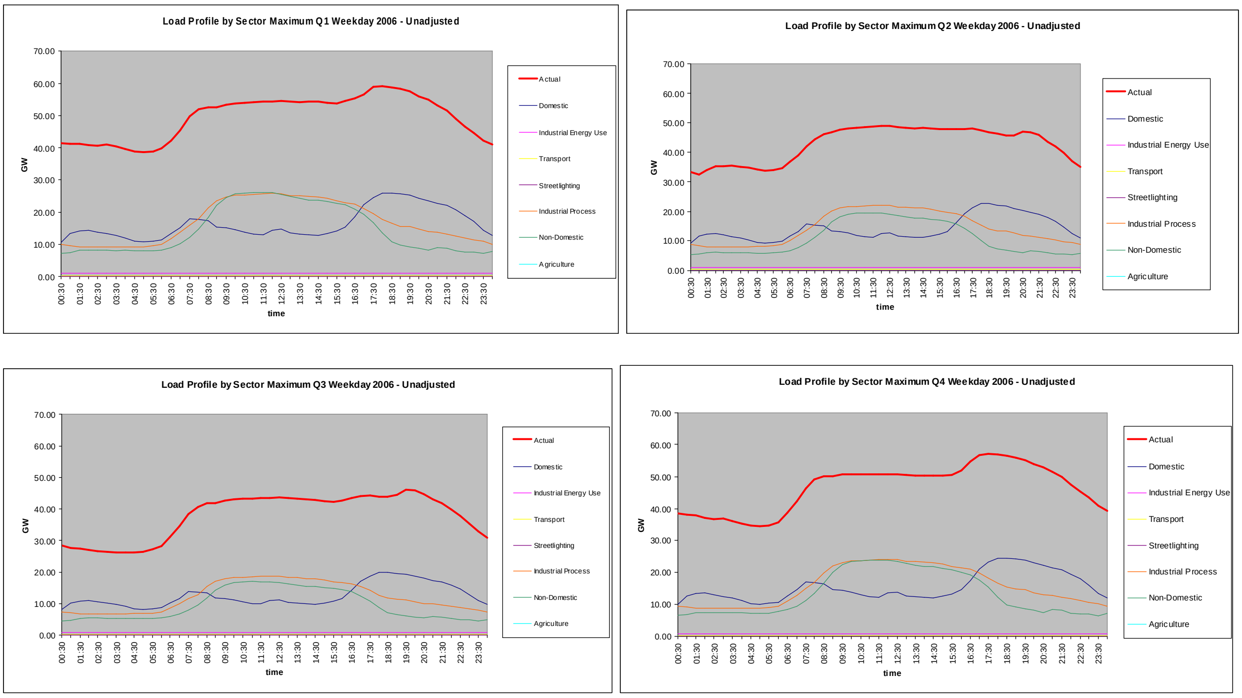

Figure 18: Quarterly demand curves by sector plotted relative to each other (unadjusted)

4.2.2 Domestic Load Profiles by End Use

Elexon data[7] on load profiles were used in the previous peak electricity demand study carried out for Defra. Unfortunately, these profiles have not been updated since the previous study, therefore these distribution profiles were used but based on the updated National Grid figures discussed above.

In addition to the Elexon data the following data sources were used and where possible data pertaining to the average daily demand profiles for each quarter were used:

- Lighting profiles and catering, heating and hot water demand profiles were based on Electricity Association[8] data for 1996/97

- Computing and consumer electronics demand profiles were based on new data obtained from a Strathclyde University case study project on electricity demand profiles. These data were gathered from a small community in Stirling (known as the “Riverside Community”) at the end use level[9]. There was also some extrapolation of this data which indicated no consumption by these end-uses between midnight and 9am which clearly cannot be the case on a national level.

- Cold appliances were assumed to have a constant profile over the course of a day

In all cases the demand profiles were reconciled to quarterly consumption figures from DUKES[2] which were in turn reconciled to take into account BRE[3] data on total domestic consumption by end use at a national level. This was achieved by revising the end use demand profiles so that the sum under the curves agreed with the expected demand on a peak day[l].

Figure 19 below shows the quarterly demand profiles by end use for the domestic sector. For each quarter the best fit of the available data is shown first as the unadjusted results. The results were then adjusted to fit with the actual demand profile. These revised results are shown in the second graph for each quarter. In general the best fit of the available data is a reasonable match to the actual demand curve; however, there is a consistent under-estimation of night time demand and to some extent evening and early morning demand. This requires further investigation but one possibility is that equipment and appliances are being left on over-night.

[l] This was achieved by adjusting the average quarterly demand profiles for lighting, heating and cooling to the expected peak demand based on the difference between the average and minimum hours of daylight, average and minimum degree days, and average and minimum maximum temperatures, respectively.

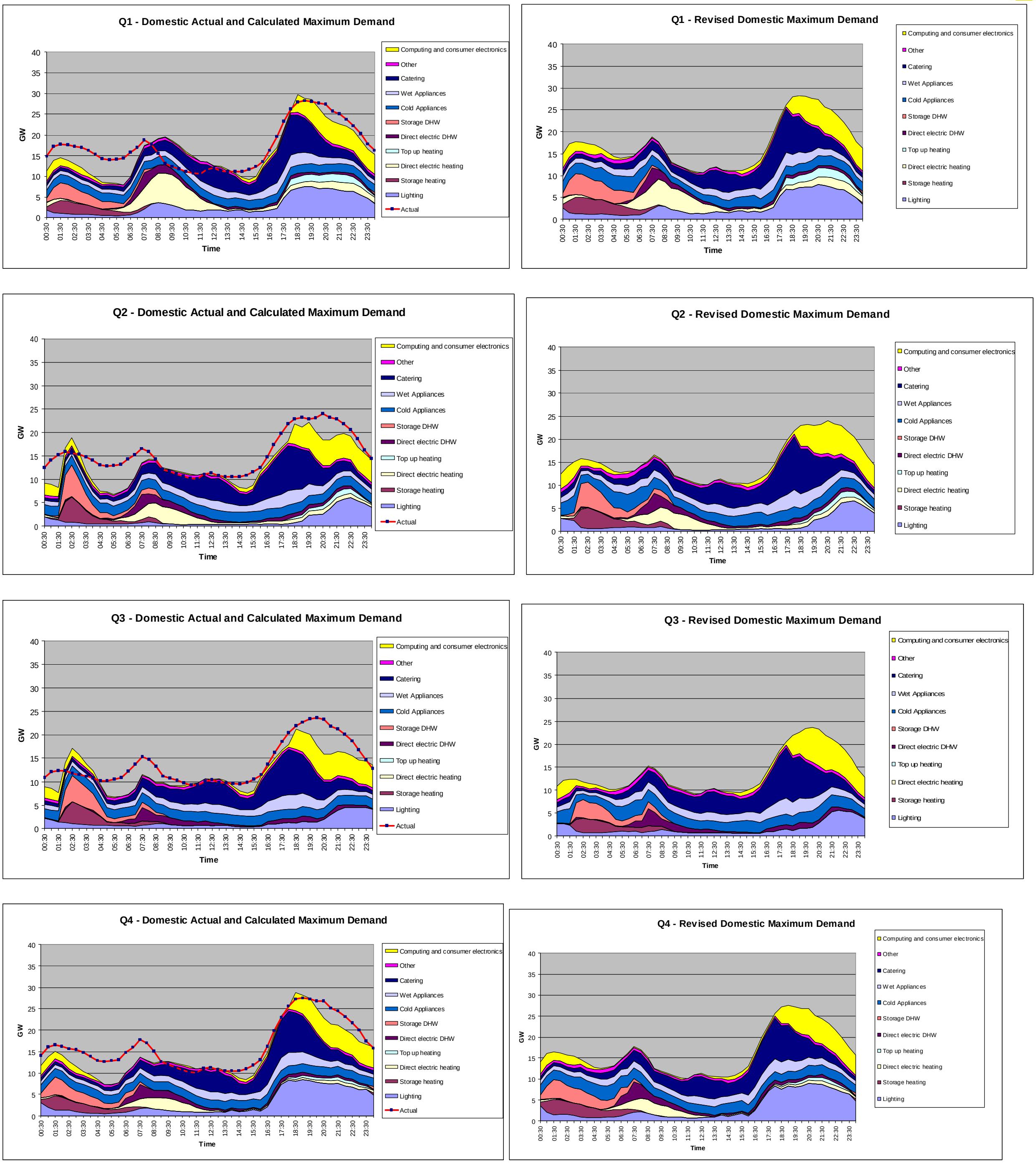

Figure 19: Quarterly demand profiles by end use for the domestic sector

Unsurprisingly, the main differences between the quarters are in demand for heating and lighting. The demand for lighting varies from only 4% of the peak in quarter 2 to 30% of the peak in quarter 4 clearly relating to availability of daylight. This is consistent to other work on domestic load profiles which found that at least 20% of the winter peak was attributable to lighting[4]. A similar variance can be seen for electric heating demand which varies from 12% of the peak in quarter 1 and 0% in quarter 3. However, the majority of electric heating is storage heating which does not contribute to the peak demand. All year round, catering and consumer electronics make up a large proportion of the peak.

Quarter 1 shows the highest peak at just over 28 GW. More detailed examination shows that three end uses account for two thirds of the peak; catering accounts for 28%, lighting for 25% and computing and consumer electronics for 14%.

4.2.3 Non-Domestic Load Profiles by End Use

The end use profiles for the non-domestic sector were based on a combination of modelled and monitored data.

In the absence of representative monitored data for the UK the cooling demand profile was based on data for California, but adjusted to UK conditions based on the differences between the external air temperature profiles for California and the UK for Quarters 2 and 3. This is less than ideal because there may well be other differences in terms of system types and the proportion of fan to chiller energy. This highlights the need for more monitoring data for the UK.

The catering demand profile was based on actual monitored data for offices, which was smoothed by averaging demand over adjacent time periods to give a more realistic representation of demand across the stock.

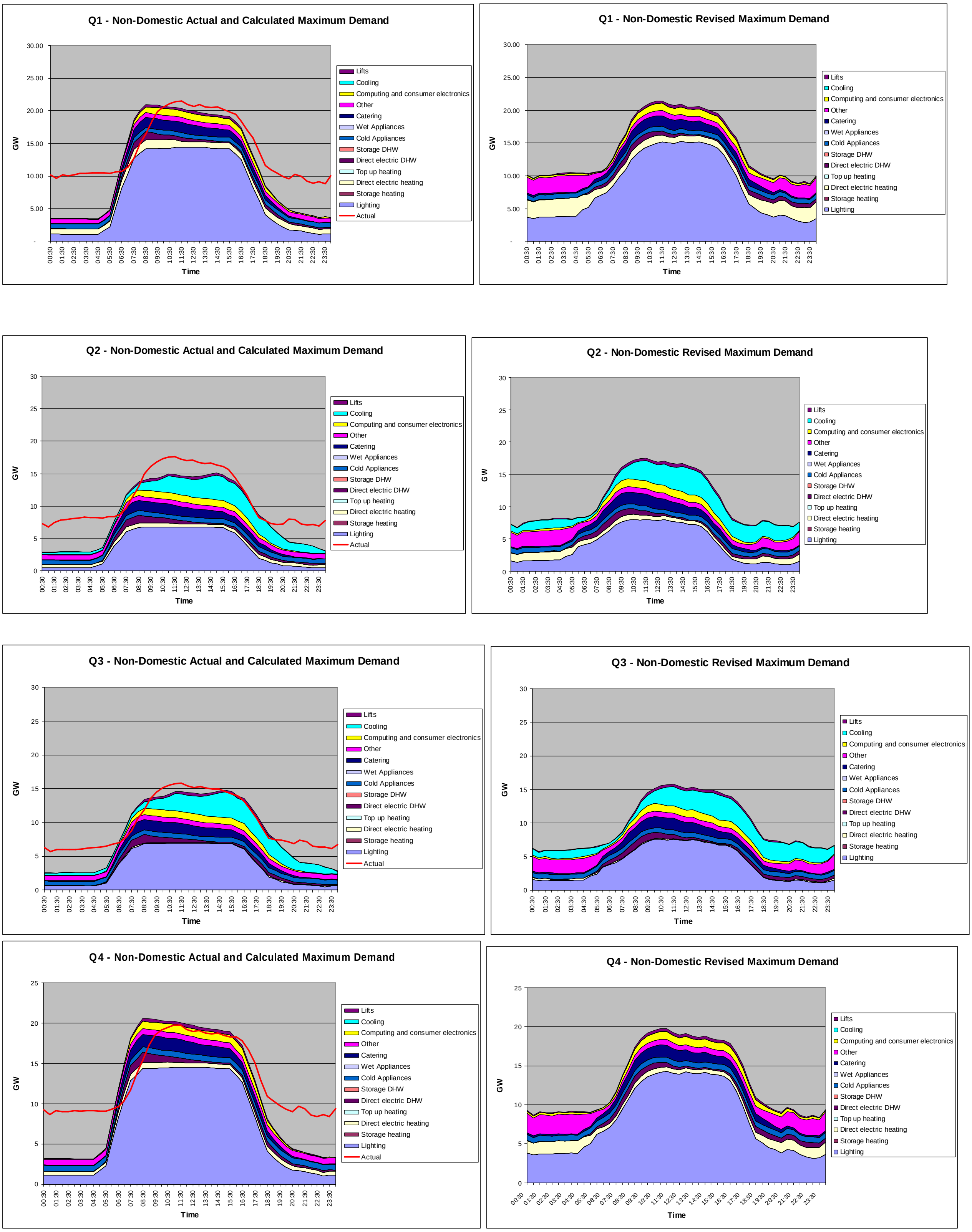

Figure 20: Quarterly demand profiles by end use for the non-domestic sector

This gives a breakdown of the building sectors and end uses that contribute to peak electricity demand across the seasons which can be used as a basis for modelling future electricity demand.

A more simplistic treatment of the other (non-building) components of electricity demand was made. Here, aside from street lighting, where the demand was assumed to be zero during average daylight hours in each quarter, it was assumed that industrial process, energy industries, transport and agriculture were responsible for an equal share of the total other electricity demand at any given time.

5 Historical Electricity Demand

We have already established that demand for electricity has been relatively constant over recent years, however, looking back it is not clear whether this levelling off is part of the long term trend or not.

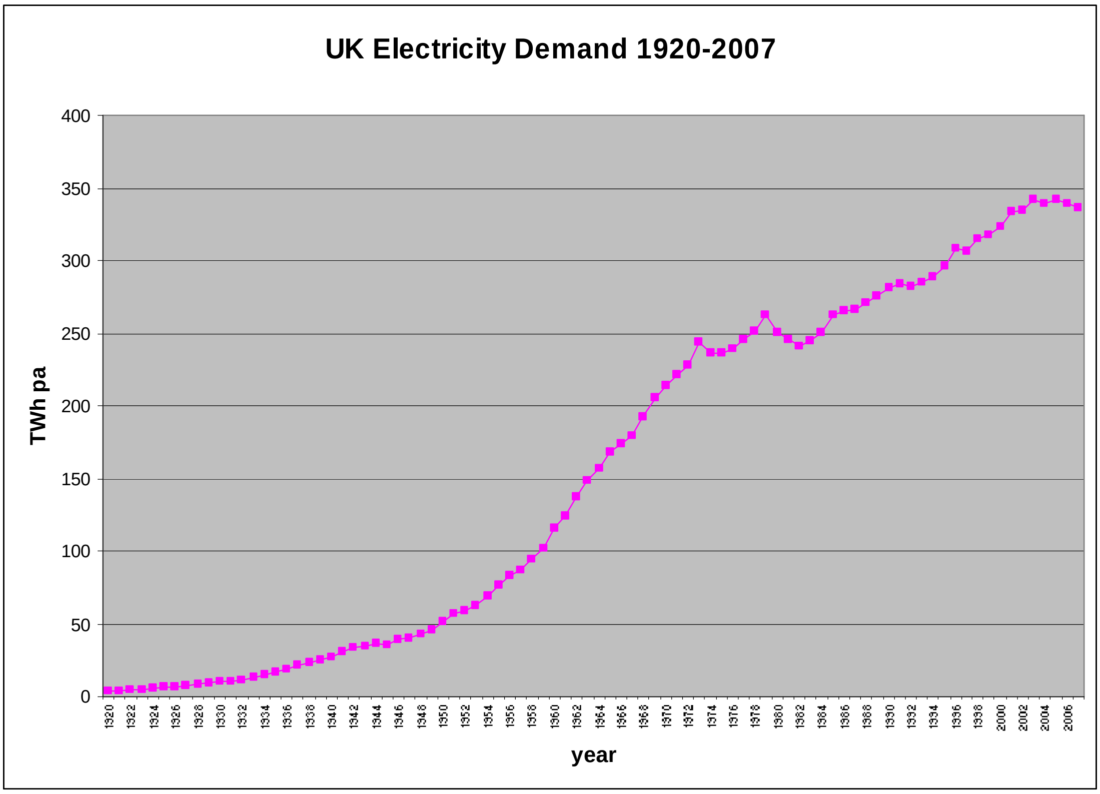

Figure 21: Historical Electricity Consumption in the UK

It would also be informative to explore long term historical trends in peak demand to see the extent to which they have changed.

Electricity use in industry and buildings (both domestic and non-domestic) accounts for around 97% of electricity use so we have concentrated on modelling demand changes in these sectors. Of the remainder agricultural energy use is not expected to significantly change in terms of its use profile or contribution to overall demand so we have assumed that demand will remain at the current level in future years. For street lighting, the most recent MTP projections were used to determine changes in the overall demand level to 2020 and that this will remain constant until 2050 with no change in the demand profile expected. Transport currently only accounts for 2% of electricity demand, and here we have assumed that the demand will remain constant in future years, which is in line with past trends. However, if there is significant switching to electric powered road vehicles in the future this could significantly increase electricity demand in this sector.

For industrial electricity use demand is much harder to predict because, unlike the other sectors, it shows significant sensitivity to economic conditions and demand can shift overseas. Whilst the overall trend in electricity use by industry is a shallow increasing trend, the rate of increase has levelled off in recent years, in part attributable to the structural changes in the industrial sector.

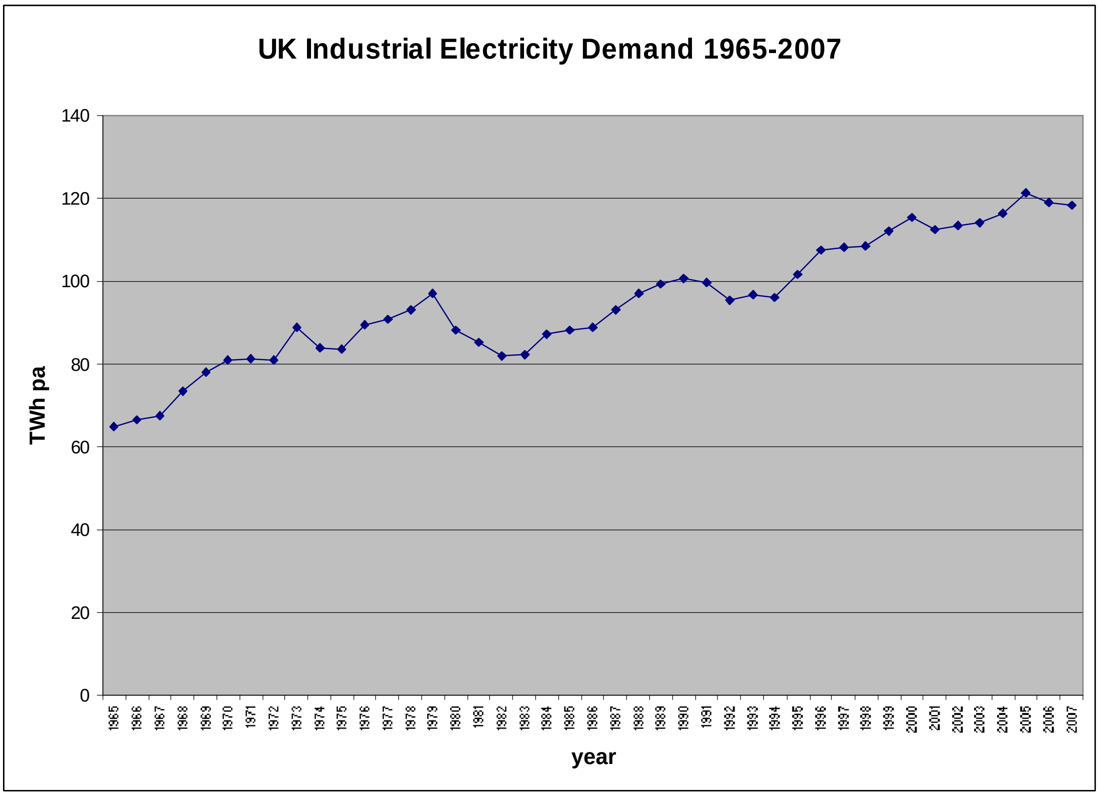

Figure 22: Historical Electricity Consumption in UK Industry

6 "Business as Usual" Scenario

A business as usual scenario for electricity demand to 2050 is needed as a basis for exploring how alternative scenarios might change the size and position of the current seasonal peaks in electricity demand. To do this we constructed a reference case based on expected changes in end user demand.

6.1 "Business as Usual" Assumptions

For domestic and non-domestic buildings, which together account for 65% of electricity consumption, the anticipated demand changes are modelled at the end use level. These changes are taken from the most recent BREHOMES and NDEEM scenario modelling results or from MTP technology models where they contain more recent data. These models take account of expected changes in the number of homes and the demand for commercial and public floor space based on population and employment projections. They also take account of changes in the thermal performance of the building envelope, changes the technologies and efficiency with which the demand for building services are met, and changes in working practices where these alter the demand for services. The scenarios results used here are "with policies" scenarios which take account of all relevant changes included in the most recent Energy White Paper[m].

For the purposes of this modelling exercise we have assumed that the industrial demand for electricity will remain stable in future years, which in line with assumptions made in the most recent BERR energy projections[n], and, in the absence of more detailed information, we have assumed that the demand profiles will not change significantly either. Whilst this assumption is plausible, it will always be difficult to predict changes in electricity demand with any degree of certainty because the demand for goods is met at a global, rather than a national level.

In all cases the sectoral/end use changes in demand are expressed in terms of a % increase (or reduction) compared to the current year and are summarised in the following table:

[m] Meeting the Energy Challenge: A White Paper on Energy, DTI, May 2007
[n] Updated Energy and Carbon Emission Projections: The Energy White Paper, BERR, February 2008.
paper

Sector	End Use	Current	2010	2020	2030	2040	2050	Source
Domestic	Lighting	0%	-10%	-17%	-23%	-29%	-34%	MTP
Domestic	Storage heating	0%	-1%	4%	14%	-9%	1%	BREHOMES
Domestic	Direct electric heating	0%	-1%	4%	14%	-9%	1%	BREHOMES
Domestic	Top up heating	0%	-1%	4%	14%	-9%	1%	BREHOMES
Domestic	Direct electric DHW	0%	-4%	-6%	-4%	0%	3%	BREHOMES
Domestic	Storage DHW	0%	-4%	-6%	-4%	0%	3%	BREHOMES
Domestic	Cold Appliances	0%	-7%	-7%	-8%	-6%	-5%	BREHOMES
Domestic	Wet Appliances	0%	4%	15%	23%	27%	32%	BREHOMES
Domestic	Catering	0%	-3%	-7%	-1%	5%	11%	BREHOMES
Domestic	Other	0%	4%	15%	23%	27%	32%	BREHOMES
Domestic	Computing and consumer electronics	0%	4%	15%	23%	27%	32%	BREHOMES
Domestic	Cooling	0%	100%	500%	1000%	1750%	2600%	BREHOMES
Non-Domestic	Lighting	0%	-5%	-14%	-14%	-14%	-14%	MTP
Non-Domestic	Direct electric heating	0%	-2%	-5%	-11%	-12%	-14%	NDEEM
Non-Domestic	Direct electric DHW	0%	3%	12%	18%	20%	24%	NDEEM
Non-Domestic	Storage DHW	0%	3%	12%	18%	20%	24%	NDEEM
Non-Domestic	Cold Appliances	0%	-7%	-7%	-8%	-6%	-5%	NDEEM
Non-Domestic	Wet Appliances	0%	4%	15%	23%	27%	32%	NDEEM
Non-Domestic	Catering	0%	-7%	-7%	-8%	-6%	-5%	NDEEM
Non-Domestic	Other	0%	4%	15%	23%	27%	32%	NDEEM
Non-Domestic	Computing and consumer electronics	0%	23%	71%	114%	153%	196%	NDEEM
Non-Domestic	Cooling	0%	14%	33%	54%	79%	108%	MTP
Non-Domestic	Lifts	0%	4%	15%	23%	27%	32%	NDEEM
Industrial Process		0%	0%	0%	0%	0%	0%	
Energy Industries		0%	0%	0%	0%	0%	0%	
Transport		0%	0%	0%	0%	0%	0%	
Agriculture		0%	0%	0%	0%	0%	0%	
Street Lighting		0%	7%	26%	26%	26%	26%	MTP

Figure 23: Table showing the Percentage Change in Electricity Demand Assumed for the "Business as Usual" Scenario

NB. Although the % increase in domestic cooling is very large, because electricity use for cooling is currently tiny domestic demand for cooling is only expected to account for a small proportion of domestic electricity demand by 2050.

The lighting figure includes the phase-out of GLS lamps and the move to more efficient lighting. Whilst for heating the combined effect of growth in demand for heating, and the increase in the thermal performance of the building stock over time result in electric heating increasing to 2030 and declining thereafter.

6.2 Business as usual Electricity Demand Profiles.

The results of applying the Business as usual changes in demand on the quarterly peak demand profiles are shown in the following charts and tables.

Quarterly Peak Electricity Demand for BAU Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	48.99	46.29	55.98
2020	57.85	49.75	47.93	55.65
2030	59.20	51.62	50.21	56.81
2040	59.51	53.69	52.42	57.49
2050	60.76	56.31	54.91	58.53

Time of Quarterly Peak Electricity Demand for BAU Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	12:30	20:00	18:30
2030	18:30	12:30	20:00	18:30
2040	18:30	17:30	19:30	18:30
2050	18:30	17:30	19:30	18:30

Figure 24: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the "Business as Usual" Scenario

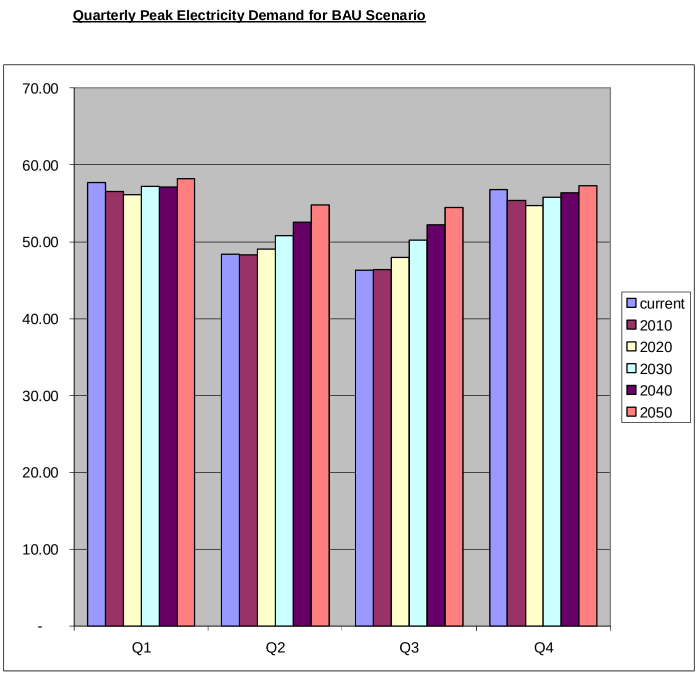

Figure 25: Quarterly Peak Electricity Demand (GW) for the "Business as Usual" Scenario

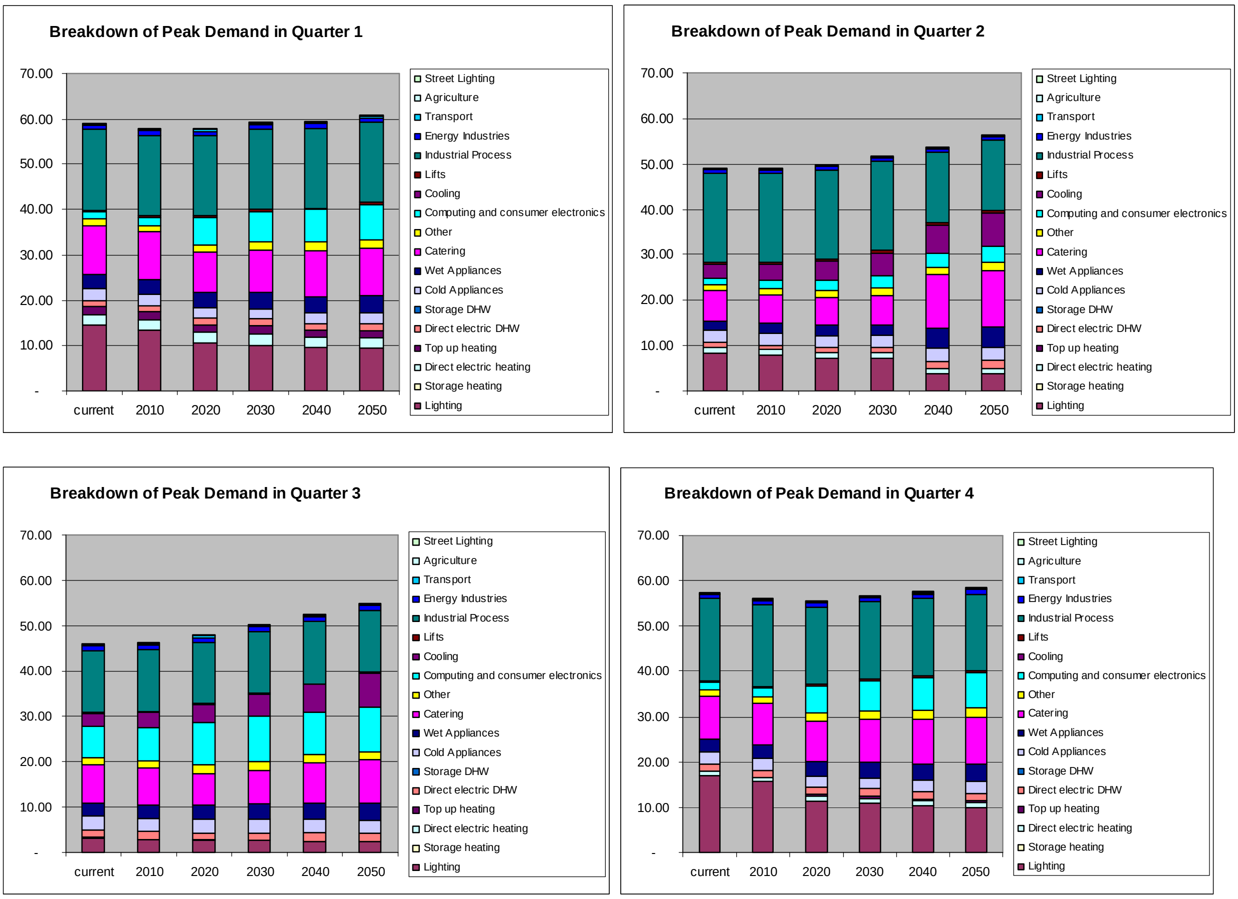

Figure 26: Quarterly Breakdown of Peak Electricity Demand (GW) by end use for the “Business as Usual” Scenario

This shows that lighting, catering, consumer electronics and, in the summer quarters cooling demand are the building end uses which make the biggest contributions and which therefore have the biggest potential for demand reduction given suitable technologies. For lighting the “business as usual” scenario already assumes significant improvements in energy efficiency through the deployment of newer technologies. It is clearly important to ensure that more efficient lighting technologies are employed in the future otherwise peak demand will be higher than suggested here, particularly in the winter quarters. During the summer quarters increased demand for cooling and computing and consumer electronics are responsible for much of the predicted increase in demand. For both these end uses it is largely changes in end user demand rather than energy efficiency improvements that dominate. (Note that the step increase in catering demand in Q2 in 2040 arises because of a change of the timing of the peak rather than an increase in the demand for catering.)

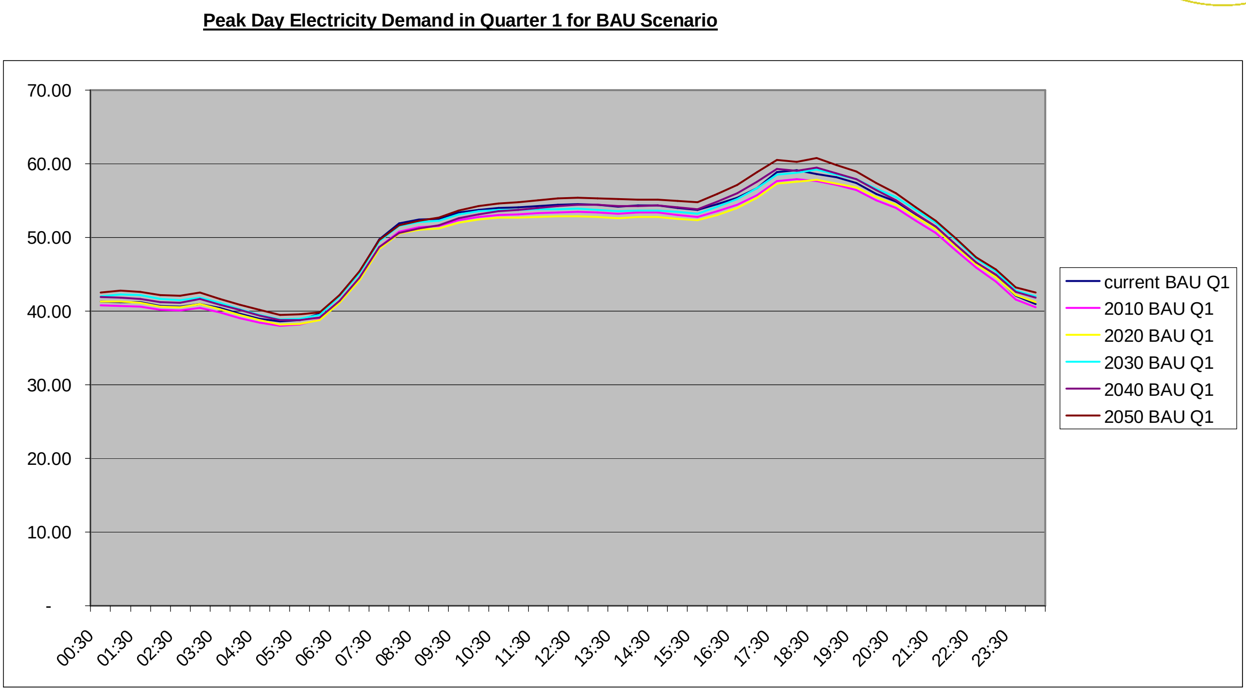

Figure 27: Electricity Demand (GW) Profile for Quarter 1 for the "Business as Usual" Scenario

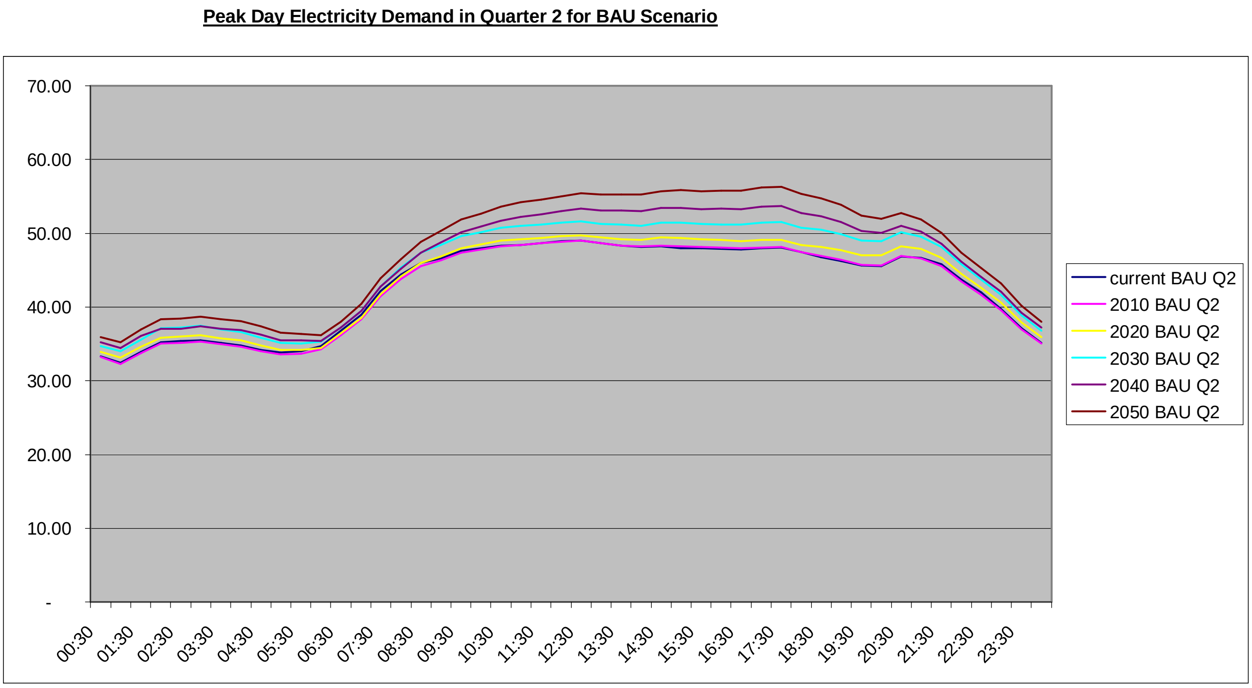

Figure 28: Electricity Demand (GW) Profile for Quarter 2 for the "Business as Usual" Scenario

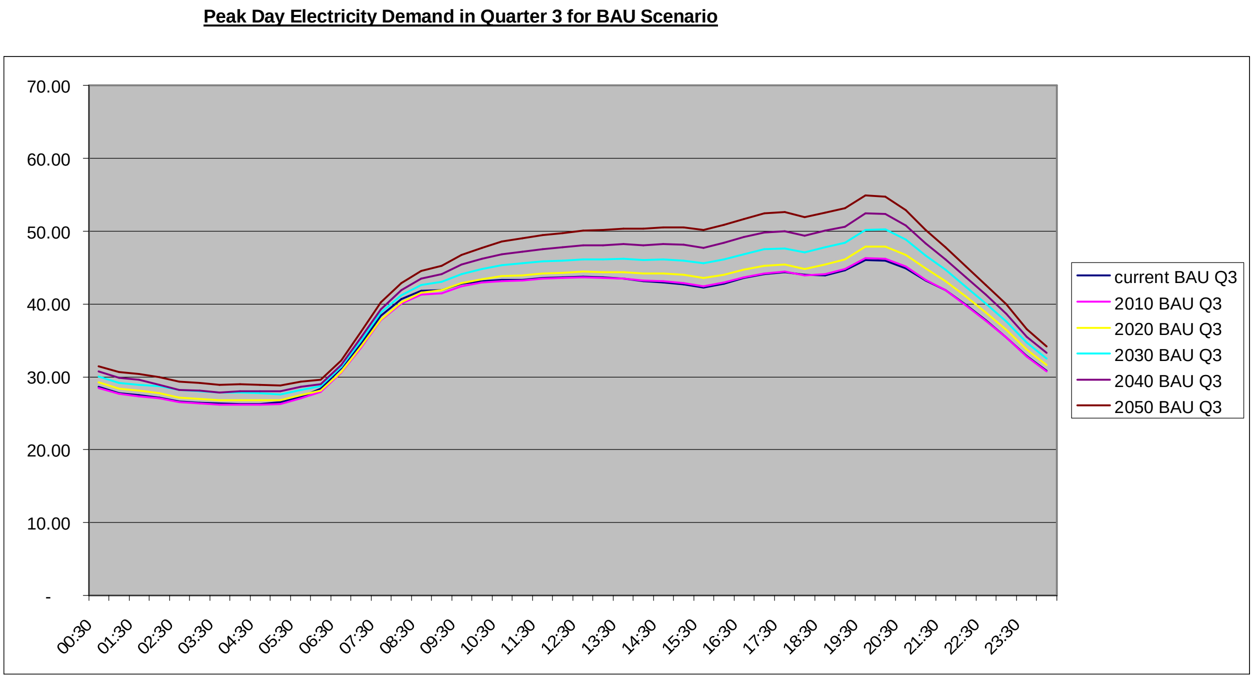

Figure 29: Electricity Demand (GW) Profile for Quarter 3 for the “Business as Usual” Scenario

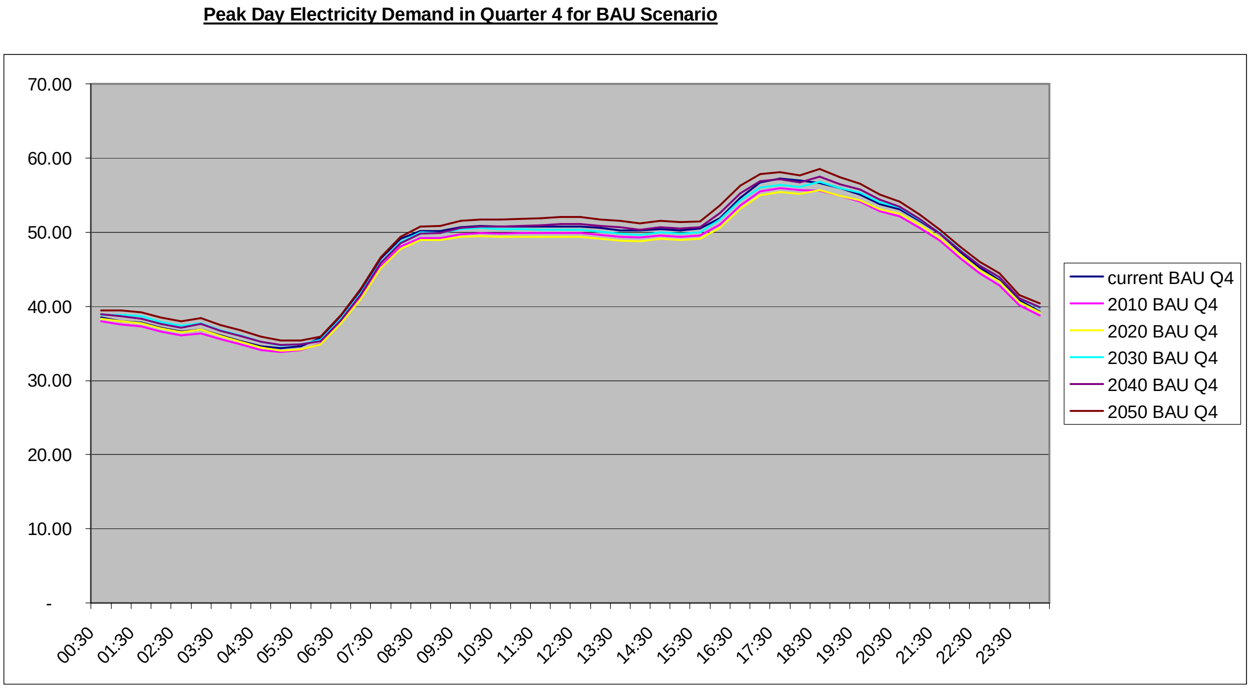

Figure 30: Electricity Demand (GW) Profile for Quarter 4 for the “Business as Usual” Scenario

In the Business as usual scenario there is a slight increase in peak demand in both Q1 and Q4, with only minor changes to the shape of the daily demand profile. Whereas in Q2 and Q3 a significant increase in daytime demand is expected due primarily to increased demand for cooling and computers and consumer electronics which can clearly be seen by comparing the current and 2050 demand profiles for Q2 and Q3, See Figures 31 to 34 below. The BAU scenario indicates that the time at which peak demand occurs in Q2 is shifting from the late morning to the afternoon, but no shift in the timing is evident in Q1, Q3 or Q4.

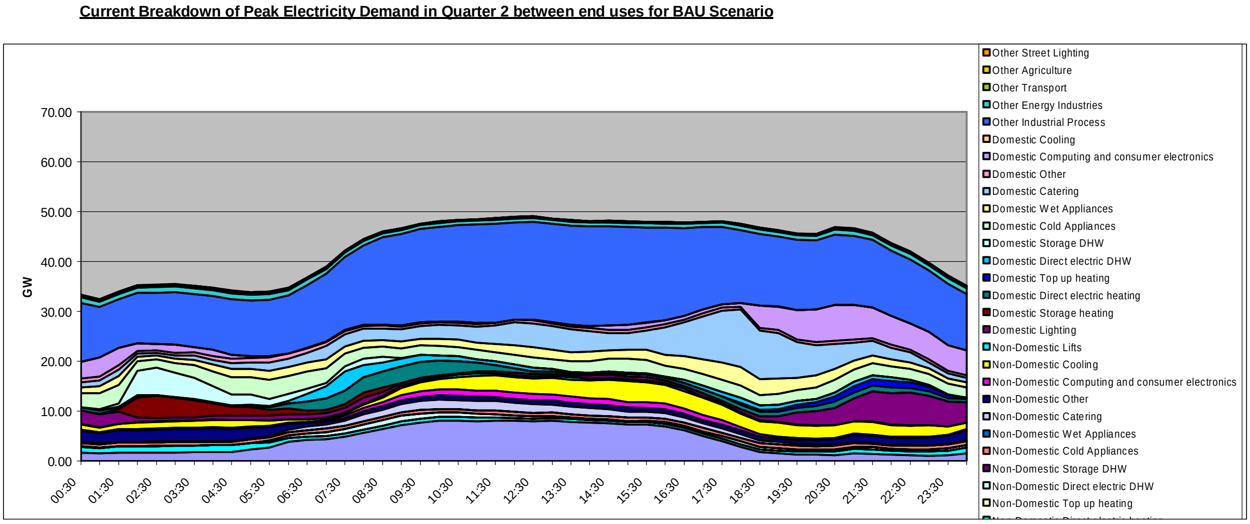

Figure 31: Current Breakdown of Electricity Demand (GW) for Quarter 2 for the "Business as Usual" Scenario

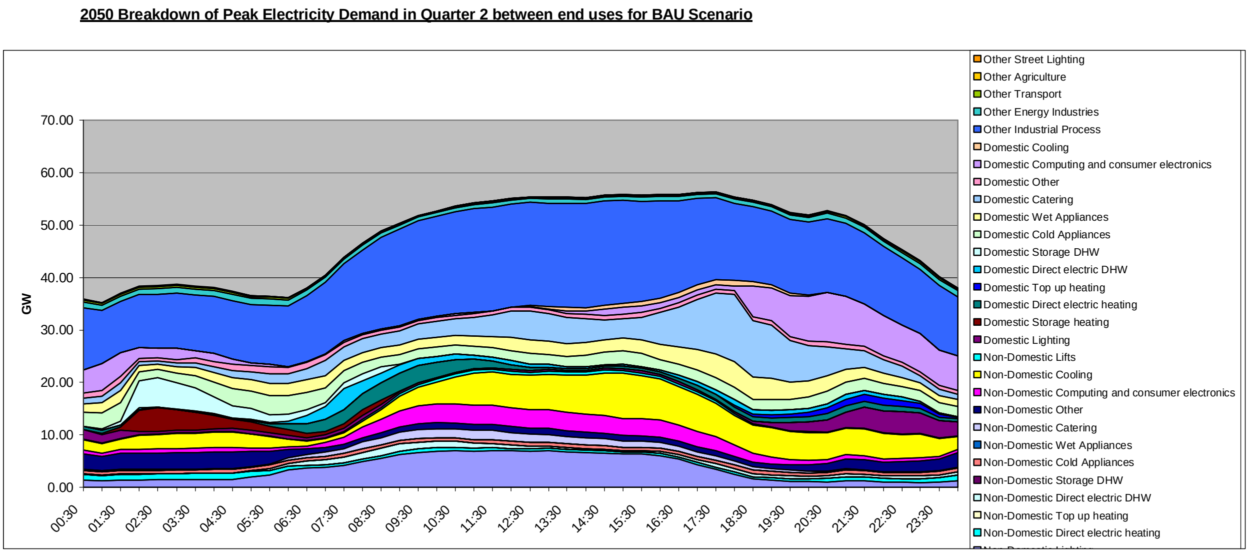

Figure 32: 2050 Breakdown of Electricity Demand (GW) for Quarter 2 for the "Business as Usual" Scenario

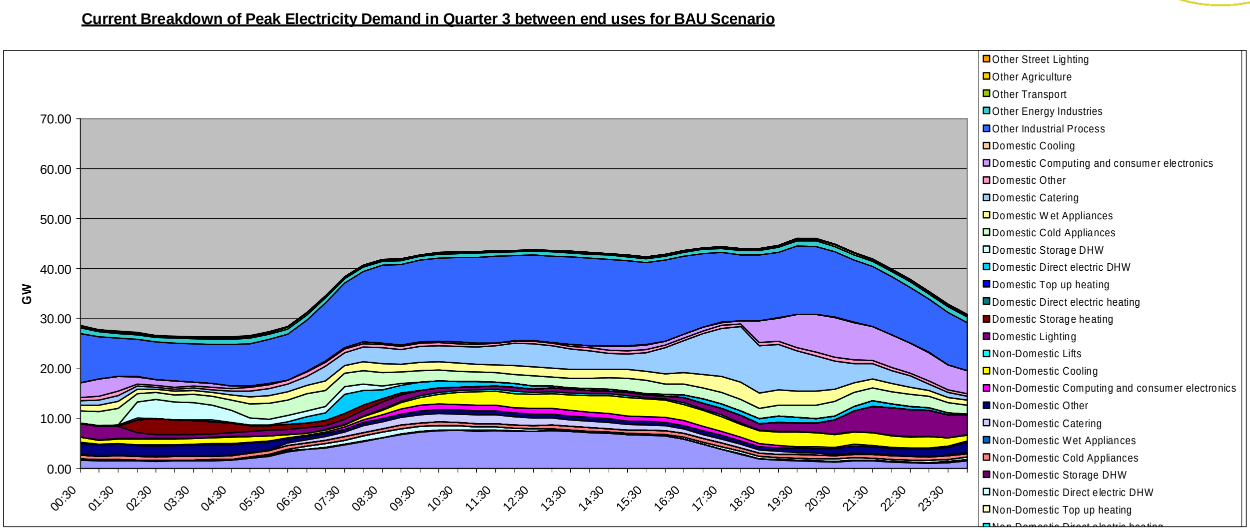

Figure 33: Current Breakdown of Electricity Demand (GW) for Quarter 3 for the "Business as Usual" Scenario

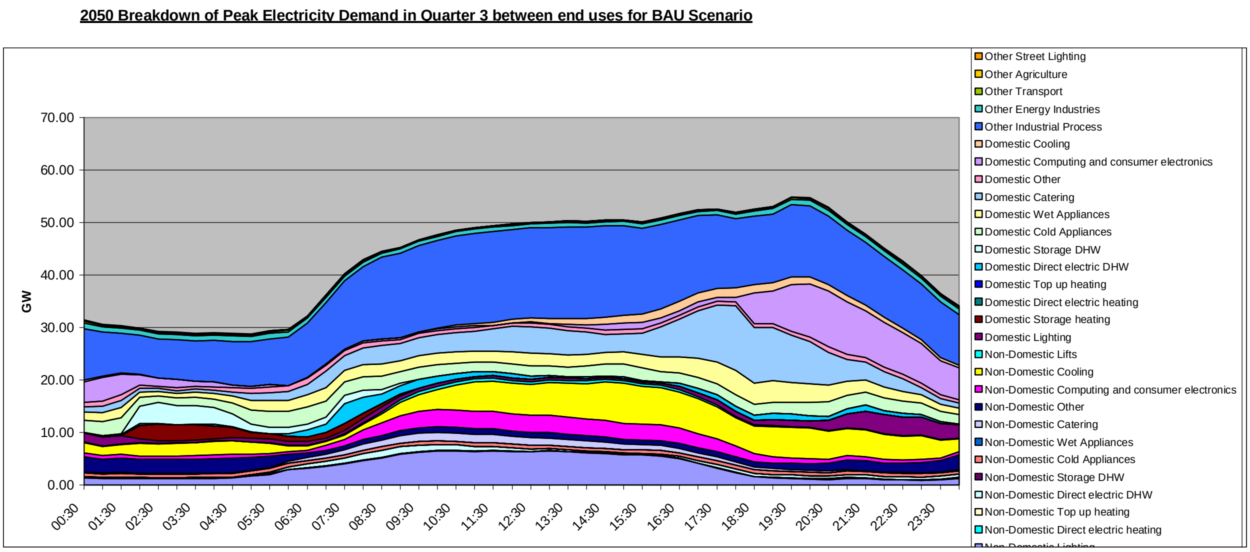

Figure 34: 2050 Breakdown of Electricity Demand (GW) for Quarter 3 for the "Business as Usual" Scenario

The spreadsheet tool also provides additional charts showing the current and projected sectoral/end use breakdown of electricity demand for the peak day in each quarter for 2010, 2020, 2030, 2040 and 2050.

The impact of these changes on the overall demand for electricity and on carbon dioxide emissions are also assessed[o] and are shown in Figures 35 to 38 below:

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[o] Assuming that the ratio between the quarterly peak and quarterly average demand remains the same in future years.

GWh	Current	2010	2020	2030	2040	2050
Agriculture	1,059	1,059	1,059	1,059	1,059	1,059
Industrial Process	124,599	124,599	124,599	124,599	124,599	124,599
Energy Industries	8,151	8,151	8,151	8,151	8,151	8,151
Transport	2,160	2,160	2,160	2,160	2,160	2,160
Street Lighting	328	351	414	414	414	414
Cold Appliances	25,246	23,564	23,420	23,342	23,755	23,937
Wet Appliances	14,115	14,687	16,240	17,341	17,959	18,680
Lifts	1,795	1,867	2,065	2,205	2,283	2,375
Catering	34,446	33,286	31,983	33,705	35,496	37,230
Other	15,493	16,120	17,824	19,033	19,711	20,503
Computing and consumer electronics	21,439	23,255	27,472	30,896	33,585	36,599
Lighting	70,773	66,060	60,567	59,283	58,098	57,004
Direct electric DHW	9,532	9,390	9,596	9,946	10,247	10,551
Storage DHW	6,494	6,233	6,113	6,265	6,492	6,673
Direct electric heating	14,919	14,640	14,861	15,178	13,366	13,946
Storage heating	5,261	5,189	5,451	6,009	4,797	5,321
Top up heating	1,653	1,631	1,713	1,888	1,508	1,672
Cooling	8,654	9,961	11,824	14,013	16,674	19,748
Total	**366,117**	**362,203**	**365,513**	**375,488**	**380,357**	**390,623**

Figure 35: Annual Electricity Consumption (GWh) broken down by Sector and End use for the "Business as Usual" Scenario

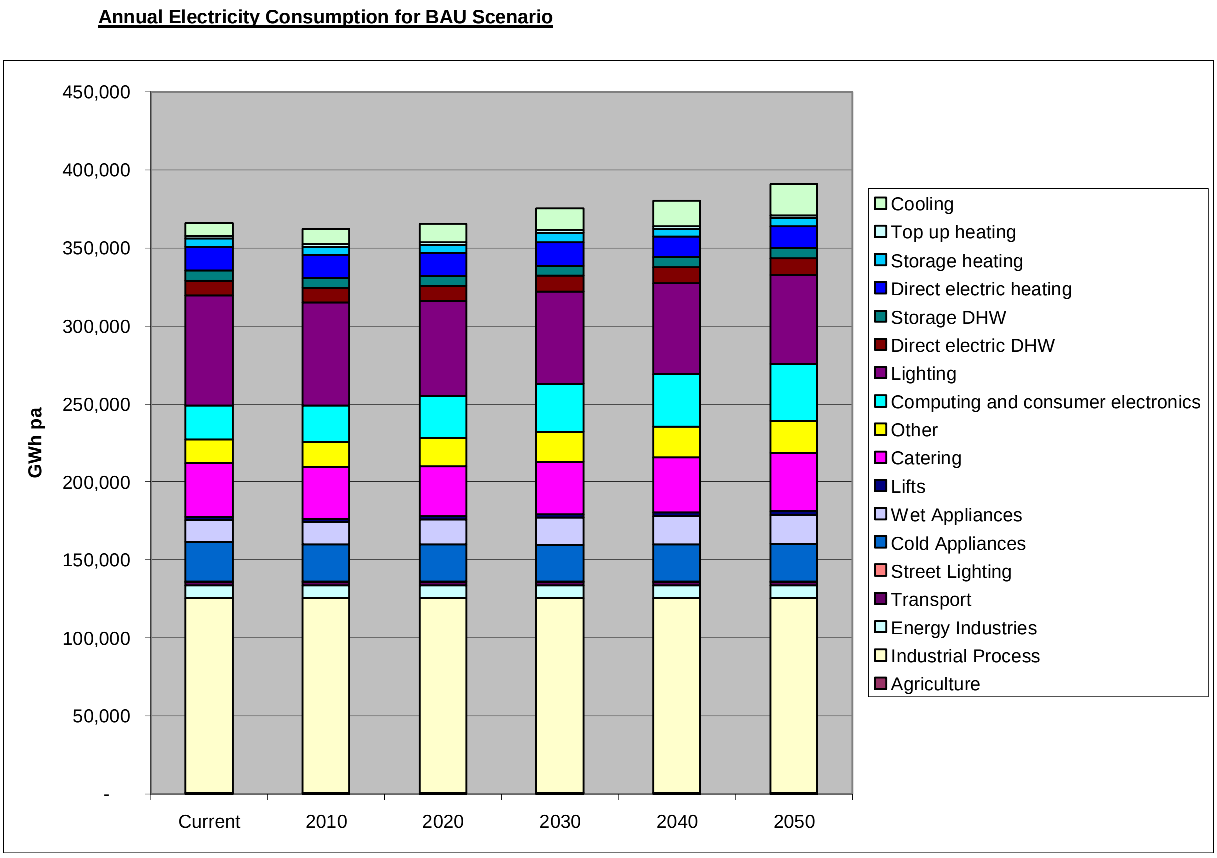

Figure 36: Annual Electricity Consumption (GWh) broken down by Sector and End use for the "Business as Usual" Scenario

M tonnes CO2	Current	2010	2020	2030	2040	2050
Agriculture	1	1	1	1	1	1
Industrial Process	67	67	67	67	67	67
Energy Industries	4	4	4	4	4	4
Transport	1	1	1	1	1	1
Street Lighting	0	0	0	0	0	0
Cold Appliances	14	13	13	13	13	13
Wet Appliances	8	8	9	9	10	10
Lifts	1	1	1	1	1	1
Catering	18	18	17	18	19	20
Other	8	9	10	10	11	11
Computing and consumer electronics	12	12	15	17	18	20
Lighting	38	35	33	32	31	31
Direct electric DHW	5	5	5	5	6	6
Storage DHW	3	3	3	3	3	4
Direct electric heating	8	8	8	8	7	7
Storage heating	3	3	3	3	3	3
Top up heating	1	1	1	1	1	1
Cooling	5	5	6	8	9	11
Total	**197**	**195**	**196**	**202**	**204**	**210**

Figure 37: Annual Carbon Dioxide Emissions broken down by Sector and End use for the "Business as Usual" Scenario

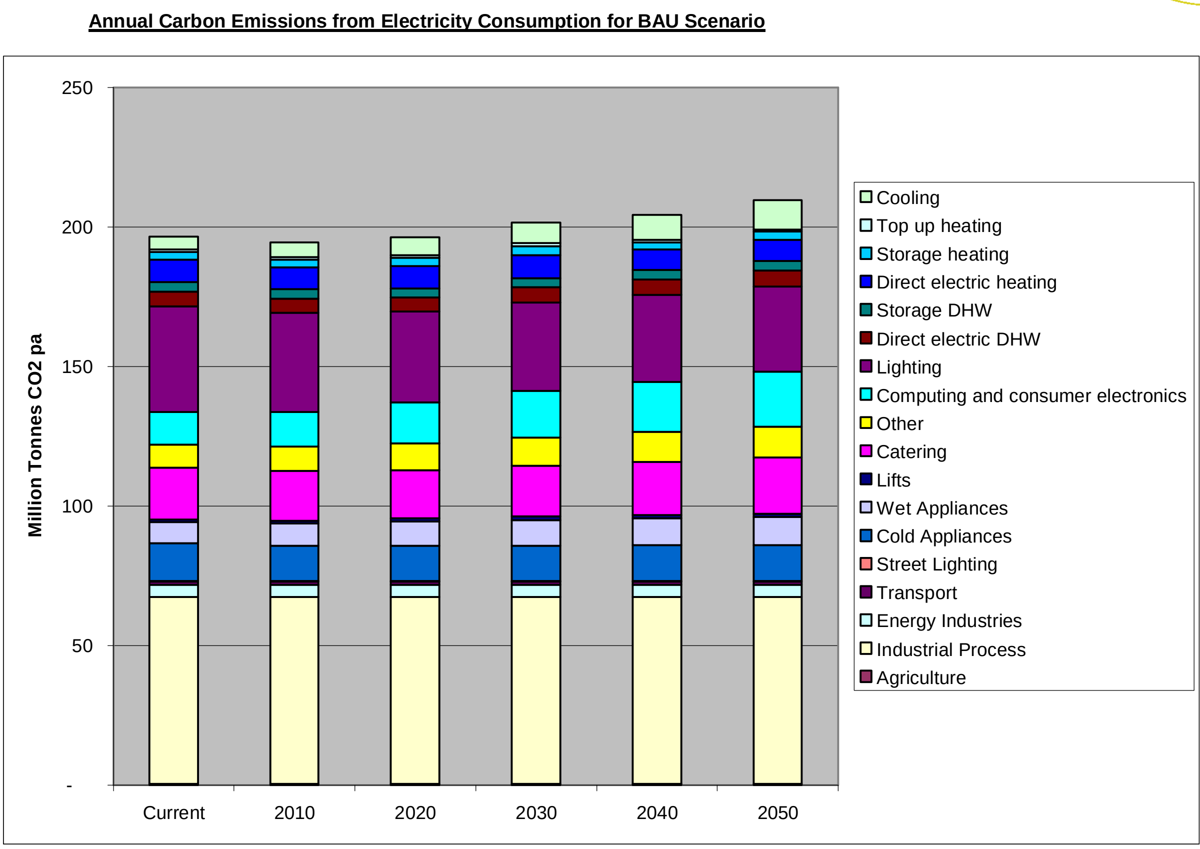

Figure 38: Annual Carbon Dioxide Emissions broken down by Sector and End use for the "Business as Usual" Scenario

The results here assume that the average annual grid electricity emissions factor of 0.537 $kgCO_2/kWh$ (the current 5 year rolling average emission factor given in DEFRA company reporting guidelines[p]) applies across all years. Clearly the actual carbon emissions will vary in the short term, depending on both the mix of plant available and their relative operation costs, and in the longer term plant built to meet the demand. Whilst the model is set up so that is possible to explore how changes in the future carbon intensities for grid electricity will impact on overall carbon emissions for the various scenario, this has not been explored here. Further modelling work would be necessary to enable the interactions between increased onsite electricity generation and the carbon intensity of grid electricity.

[p] DEFRA company reporting guidelines

7 Definitions of Other Scenarios

In addition to the BAU scenario, some additional scenarios have been developed to examine how increased uptake of on site renewable electricity generation, changes in the demand for cooling, and increased use for heat pumps will impact peak electricity demand.

The additional scenarios which have been explicitly modelled here are:

7.1 Onsite wind generation

This scenario looks at the electricity demand that might be met through significant installation of on site wind generation. For the amount of electricity generated from each GW of installed plant we use the hourly average capacity factors for each quarter. The capacity factors used was based on average wind speed data for large scale windfarms[q], but was adjusted downward by 30% to account for the lower capacities that are associated with smaller turbines[r] and potentially lower wind speeds where they are sited closer to developments.[s]

[q] http://www.eci.ox.ac.uk/publications/downloads/sinden06-windresource.pdf

[r] Here we are assuming that the wind turbines installed will not be small roof mounted models, but larger models that might for example be sited on a school playing field. Even so, this is likely to be an optimistic value as the capacity factor could be significantly lower as many housing estates are not at all windy, and could have annual wind speeds as low as 4 -5 m/s at 50m height. Based on the standard assumptions for Weibull parameters for Northern Europe in the Danish Wind Energy Association website, this could mean capacity factors of 8%-15%.

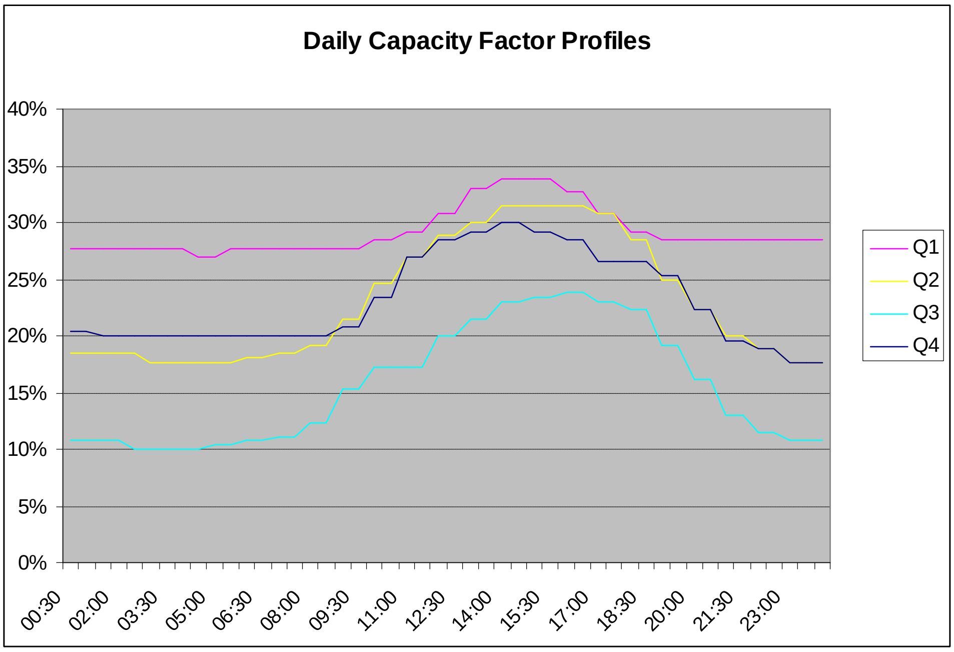

Figure 39: Capacity Factors for Wind Profiles

Further work would be required to assess the extent to which installation on such a large scale is feasible and the ability of the market to meet the demand.

7.2 Onsite PV generation

This scenario represents the electricity demand that might possibly be met through the installation of on site PV generation. The amount of electricity generated from each GW of installed plant was estimated using the following capacity factors which are based on the average solar radiance for February, May, August and November (for Q1, Q2, Q3 and Q4, respectively) on a fixed plane and assuming that 100% capacity is achieved only at the peak[t].

Further work would be required to assess the extent to which installation on such a large scale is feasible and the ability of the market to meet the demand.

7.3 Heat pumps

This scenario represents the additional electricity demand that would arise from replacing standard boiler based heating systems with electric heat pumps across all building types and takes no account of the ability of the market to meet the demand. Here we have assumed that the heat pumps have been sized so that when heating demand is at its highest the average capacity factor is 70%[u].

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[t] This gives an average annual capacity of 13% which is in reasonable agreement with the 10% figure given in the RAB report “on site renewables for zero carbon homes”

[u] This undersizing is in line with industry practice, private communication Michael Swainson, BRE

In practice this undersizing is likely to be compensated by longer run hours. If heat pumps were used to replace existing electric heating (perhaps currently the most financially attractive option) demand for space heating electricity would fall to between ¼ and 1/3 of its current levels. Also, heat pumps can provide a hot water service. These aspects were considered in the simplistic heat pump scenario that was developed for this study. More detailed modelling would be needed to explore how different operational hours, replacement of existing electric heating systems and the use of heat pumps to supply hot water would impact on demand.

Further modelling would be needed to gain a better understanding of the effect of such changes in the heat demand profile on the overall demand profile.

7.4 Zero carbon new build

This scenario represents the expected increase in onsite renewables and heat pumps that are expected to be needed to meet the requirements for zero carbon housing[v] from 2016 and zero carbon non-domestic buildings from 2019. The estimates of the amount of additional installed capacity required are based on those given in a recent report produced by the Renewables Advisory Board[w], and extrapolated beyond 2019. The RAB estimates take some account of the extent to which the market might be able to meet the demand, but this does not apply to the estimates which were extrapolated to 2050. Maximum onsite generation and more widespread installation of heat pumps.

This scenario represents the theoretical maximum electricity demand that it would be possible to meet through the installation of on site renewable generation (PV and wind) plus the additional electricity demand that would arise from replacing a significant proportion of standard boiler based heating systems with heat pumps across all building types. Further work would be required to assess the extent to which installation on such a large scale is feasible and the ability of the market to meet the demand.

7.5 High Growth cooling

In this scenario the growth of air conditioning (in both the domestic and non-domestic sectors) is doubled compared to the Business As Usual scenario.

7.6 Limit cooling

In this scenario the growth of air conditioning (in both the domestic and non-domestic sectors) is limited compared to the Business as usual scenario so that by 2050 demand for cooling is 30% less. This could be achieved by demanding more efficient equipment and reducing loads.

Solar thermal water heating would be likely to displace a mixture of electric and fossil fuel water heating. Impact on winter peak electricity demands would probably be small.

The installed capacity of onsite renewables and heat pumps, and changes in cooling demand associated with these scenarios is summarised in the following table:

[v] Here zero carbon is taken to mean zero net carbon, so there would be imports from the grid at some times and exports at others.
[w] "Role on onsite renewable generation on zero carbon homes", Renewables Advisory Board

Scenario Definition	Year	Zero carbon new build	On site wind	On site PV	Heat pumps	Renewables and heat pumps	High Growth Cooling	Limit Cooling
on site wind - GW installed by year	2010	0.005	0.005	-	-	0.005	-	-
	2020	0.22	0.44	-	-	0.44	-	-
	2030	0.44	1.77	-	-	1.77	-	-
	2040	0.66	3.54	-	-	3.54	-	-
	2050	0.88	7.07	-	-	7.07	-	-
on site PV - GW installed by year	2010	-	-	0.005	-	0.005	-	-
	2020	2.20	-	4.40	-	4.40	-	-
	2030	4.39	-	8.79	-	8.79	-	-
	2040	6.59	-	17.59	-	17.59	-	-
	2050	8.78	-	35.17	-	35.17	-	-
Domestic heat pump - GW installed by year	2010	0.01	-	-	0.01	0.01	-	-
	2020	0.08	-	-	0.32	0.32	-	-
	2030	0.16	-	-	1.29	1.29	-	-
	2040	0.24	-	-	5.10	5.10	-	-
	2050	0.32	-	-	10.21	10.21	-	-
Domestic heat pump - GW installed by year	2010	0.00	-	-	0.00	0.00	-	-
	2020	0.02	-	-	0.08	0.08	-	-
	2030	0.04	-	-	0.32	0.32	-	-
	2040	0.06	-	-	1.28	1.28	-	-
	2050	0.08	-	-	2.55	2.55	-	-
Change in cooling demand compared to BAU	2010	-	-	-	-	-	20%	-10%
	2020	-	-	-	-	-	40%	-20%
	2030	-	-	-	-	-	60%	-30%
	2040	-	-	-	-	-	80%	-30%
	2050	-	-	-	-	-	100%	-30%

Figure 40: Summary of the Changes in Installed Equipment and Cooling Demand Assumed for Each Scenario

8 Scenario Results

The following sections show how the scenarios described above are expected to impact on peak electricity demand.

8.1 Onsite Wind Generation

Quarterly Peak Electricity Demand for wind Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	48.99	46.29	55.98
2020	57.72	49.62	47.85	55.54
2030	58.68	51.11	49.92	56.34
2040	58.48	52.60	51.80	56.55
2050	58.69	54.13	53.62	56.65

Time of Quarterly Peak Electricity Demand for wind Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	12:30	20:00	18:30
2030	18:30	12:30	20:00	18:30
2040	18:30	17:30	20:00	18:30
2050	18:30	17:30	20:00	18:30

Figure 41: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the Onsite Wind Generation Scenario

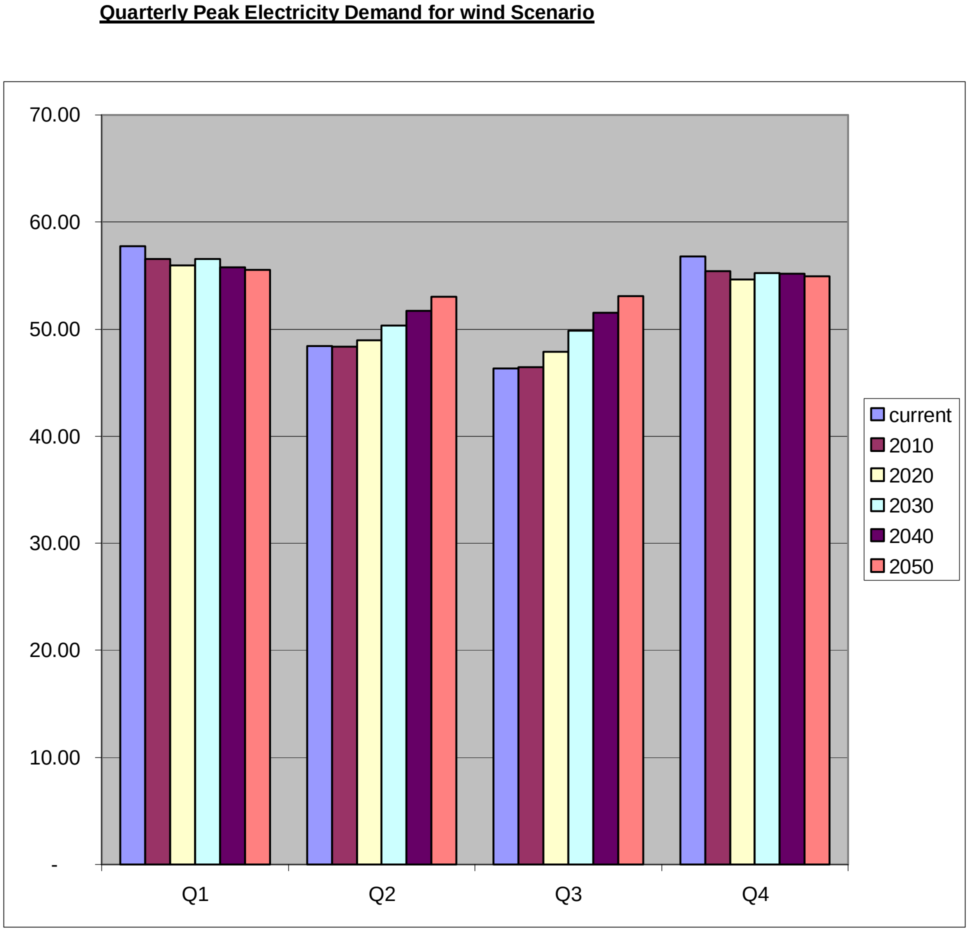


Figure 42: Quarterly Peak Electricity Demand (GW) for the Onsite Wind Generation Scenario

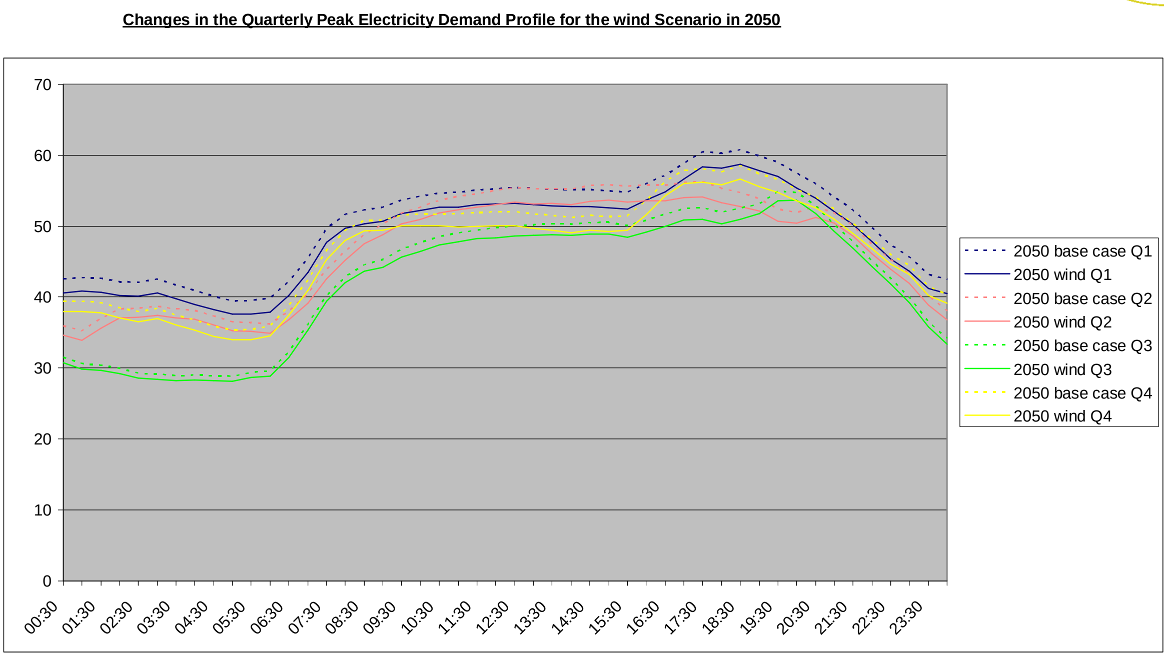


Figure 43: Quarterly Electricity Demand (GW) for the Onsite Wind Generation Scenario

Compared to the BAU scenario the installation of significant amounts of on site wind generation would reduce the annual peak demand by 3 % by 2050, and lead to a 3% decrease in annual electricity demand.

8.2 Onsite PV generation

Quarterly Peak Electricity Demand for solar Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	48.99	46.29	55.98
2020	57.85	48.29	47.93	55.65
2030	59.20	50.12	50.21	56.81
2040	59.51	50.99	52.37	57.49
2050	60.76	52.78	54.76	58.53

Time of Quarterly Peak Electricity Demand for solar Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	20:30	20:00	18:30
2030	18:30	20:30	20:00	18:30
2040	18:30	20:30	20:00	18:30
2050	18:30	20:30	20:00	18:30

Figure 44: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the Onsite PV Generation Scenario

Quarterly Peak Electricity Demand for solar Scenario

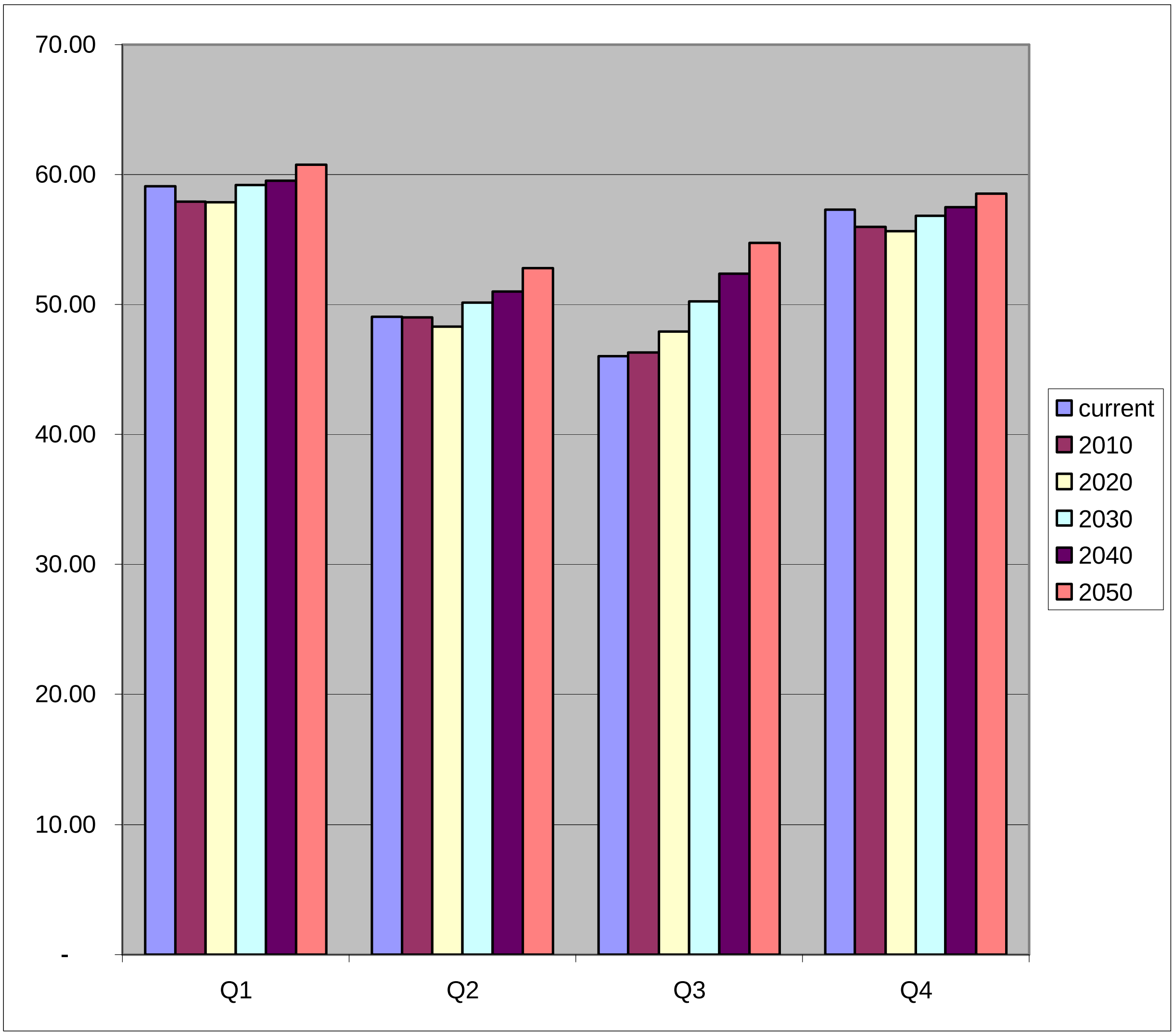


Figure 45: Quarterly Peak Electricity Demand (GW) for the Onsite PV Generation Scenario

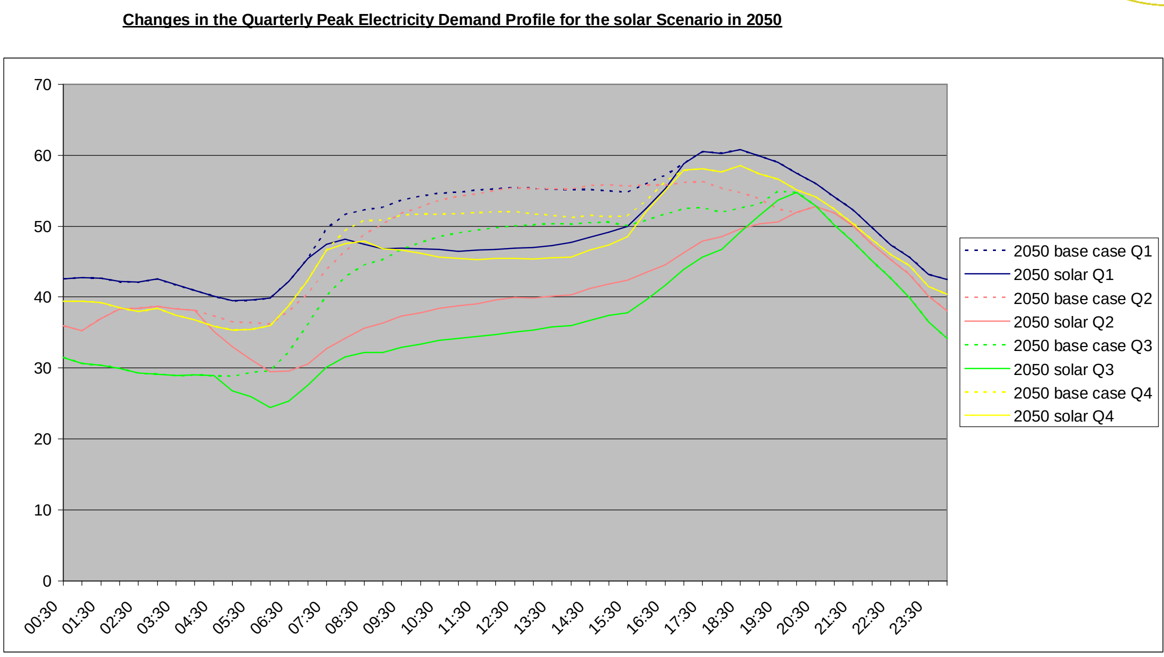


Figure 46: Quarterly Electricity Demand (GW) for the Onsite PV Generation Scenario

This scenario shows that, although the installation of onsite PV electricity generation will lead to a significant reduction in electricity demand, amounting to 9% of annual demand, overall peak demand is unaffected because this occurs on winter evenings. However, this scenario does indicate that PV would significantly reduce peak demand during Q2 (around 7%), which could become important if cooling demand were to increase at a faster rate than anticipated. Also, the higher levels of onsite generation during the middle of the day mean that in Q2 and Q3 the timing of the peak demand shifts from the middle of the day to the early evening.

8.3 Heat pumps

Quarterly Peak Electricity Demand for heatpumps Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	48.99	46.29	55.98
2020	57.89	49.78	47.93	55.67
2030	59.36	51.72	50.21	56.87
2040	60.17	54.21	52.42	57.75
2050	62.08	57.35	54.91	59.04

Time of Quarterly Peak Electricity Demand for heatpumps Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	12:30	20:00	18:30
2030	18:30	12:30	20:00	18:30
2040	18:30	17:30	19:30	18:30
2050	18:30	17:30	19:30	18:30

Figure 47: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the Heat Pumps Scenario

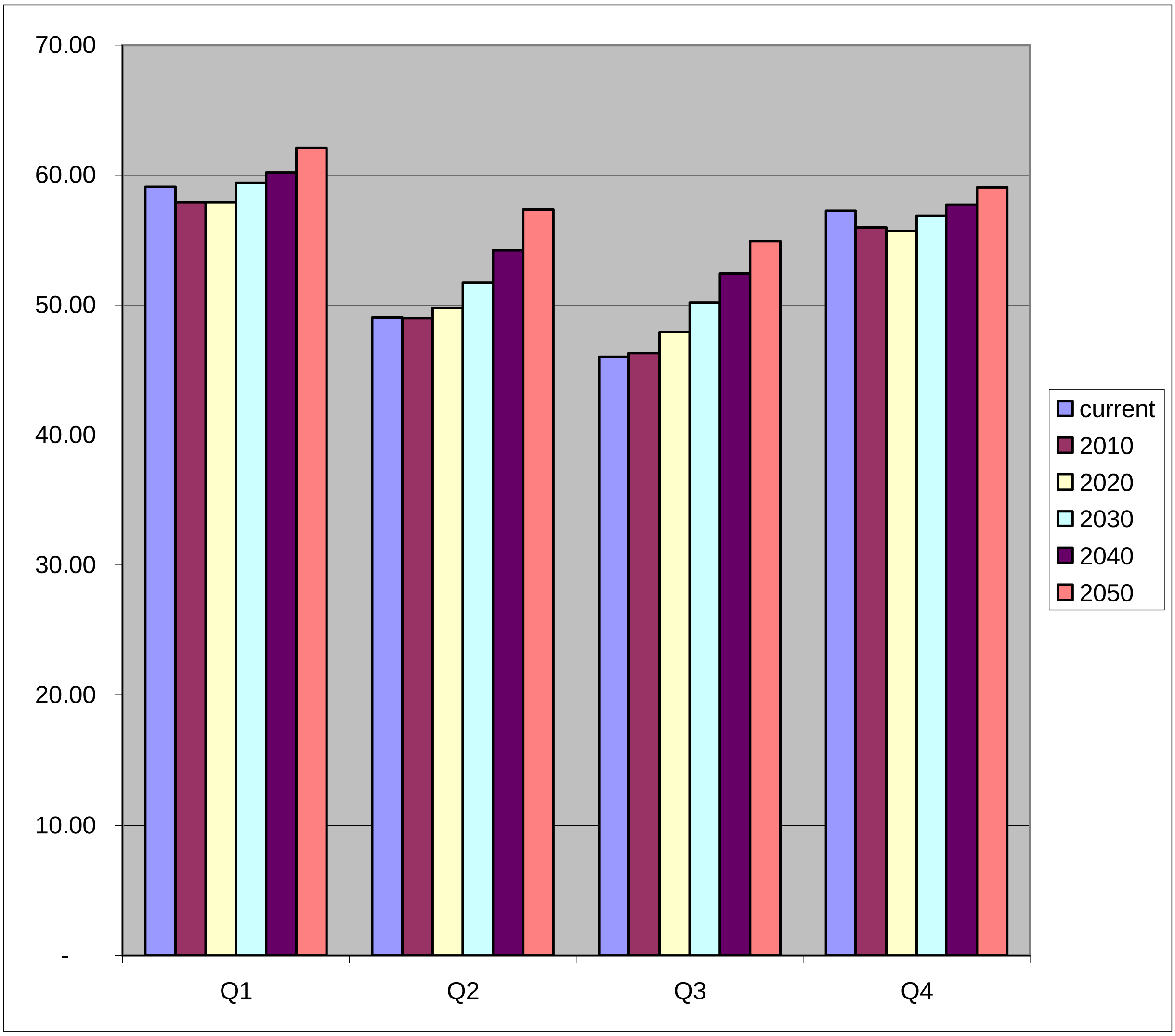


Figure 48: Quarterly Peak Electricity Demand (GW) for the Heat Pumps Scenario

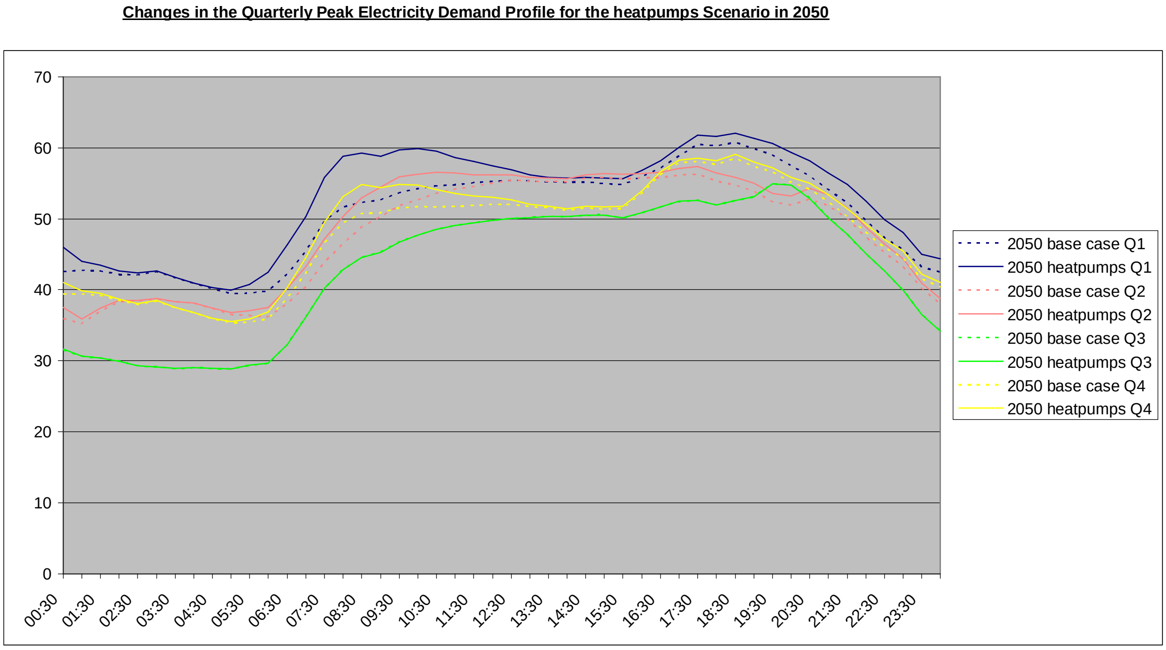


Figure 49: Quarterly Electricity Demand (GW) for Heat Pumps Generation Scenario

This scenario shows that switching away from traditional boilers to heat pumps could results in a 2% increase in the annual demand for electricity, and a 2% increase in peak electricity demand by 2050. Although there is no shift in the timing of the peaks both the morning and evening peaks in Q1 and Q4 are more pronounced.

8.4 Zero carbon new build

Quarterly Peak Electricity Demand for zero carbon new build Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	48.99	46.29	55.98
2020	57.79	48.73	47.89	55.60
2030	59.09	50.37	50.14	56.70
2040	59.35	51.93	52.26	57.33
2050	60.54	53.97	54.62	58.31

Time of Quarterly Peak Electricity Demand for zero carbon new build Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	12:30	20:00	18:30
2030	18:30	17:30	20:00	18:30
2040	18:30	17:30	20:00	18:30
2050	18:30	17:30	20:00	18:30

Figure 50: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the Zero Carbon New Build Scenario

Quarterly Peak Electricity Demand for zero carbon new build Scenario

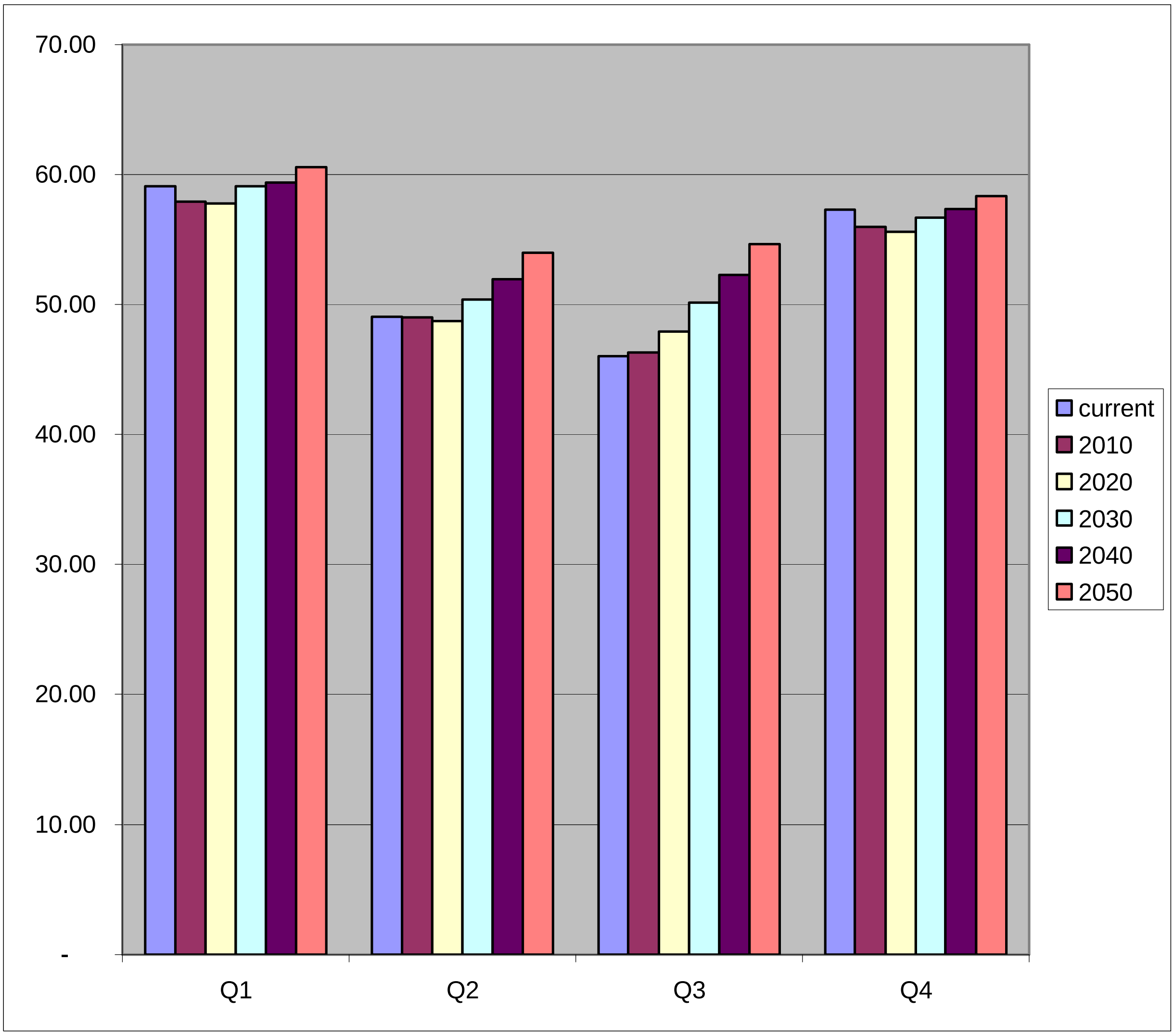


Figure 51: Quarterly Peak Electricity Demand (GW) for the Zero Carbon New Build Scenario

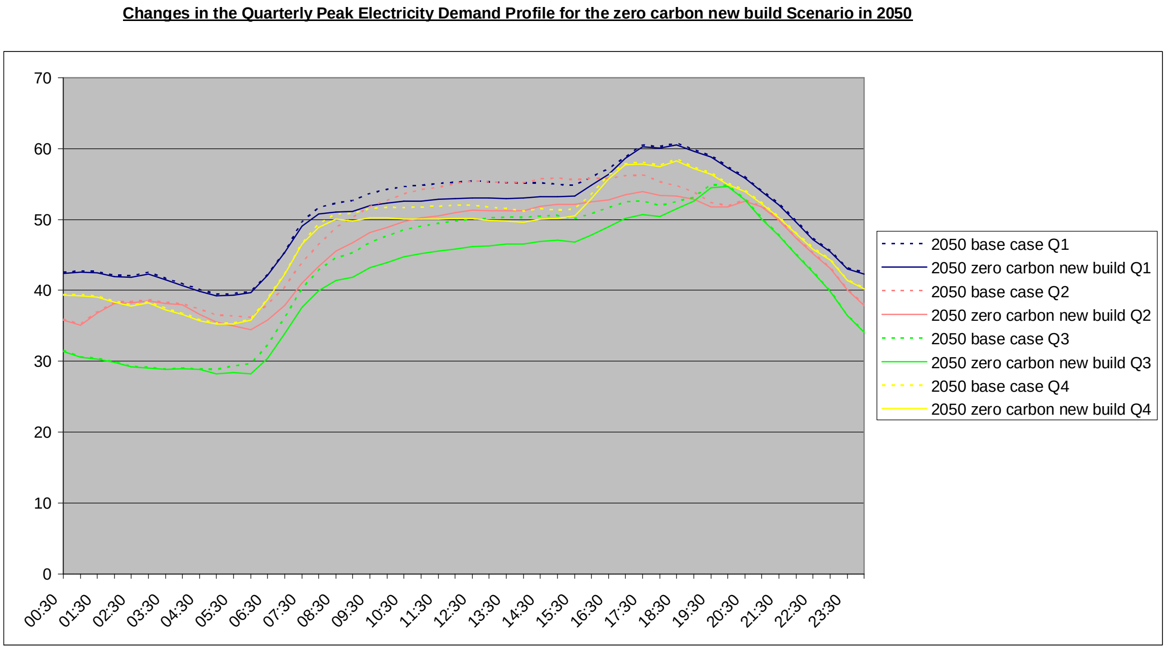


Figure 52: Quarterly Electricity Demand (GW) for Zero Carbon New Build Generation Scenario

This scenario, which represents the levels of increase in installation of on site wind and PV electricity generation and heat pumps that would be needed to meet the proposed zero carbon new build targets, results in a 2% increase in electricity demand, but no significant change in the size or the timing of peak demand.

8.5 Maximum onsite generation and heat pumps

Quarterly Peak Electricity Demand for max Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	48.99	46.29	55.98
2020	57.76	48.24	47.85	55.55
2030	58.85	49.92	49.92	56.40
2040	59.14	50.95	51.80	56.81
2050	60.01	52.71	53.62	57.16

Time of Quarterly Peak Electricity Demand for max Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	20:30	20:00	18:30
2030	18:30	20:30	20:00	18:30
2040	18:30	20:30	20:00	18:30
2050	18:30	20:30	20:00	18:30

Figure 53: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the Maximum onsite generation and heat pumps Scenario

Quarterly Peak Electricity Demand for max Scenario

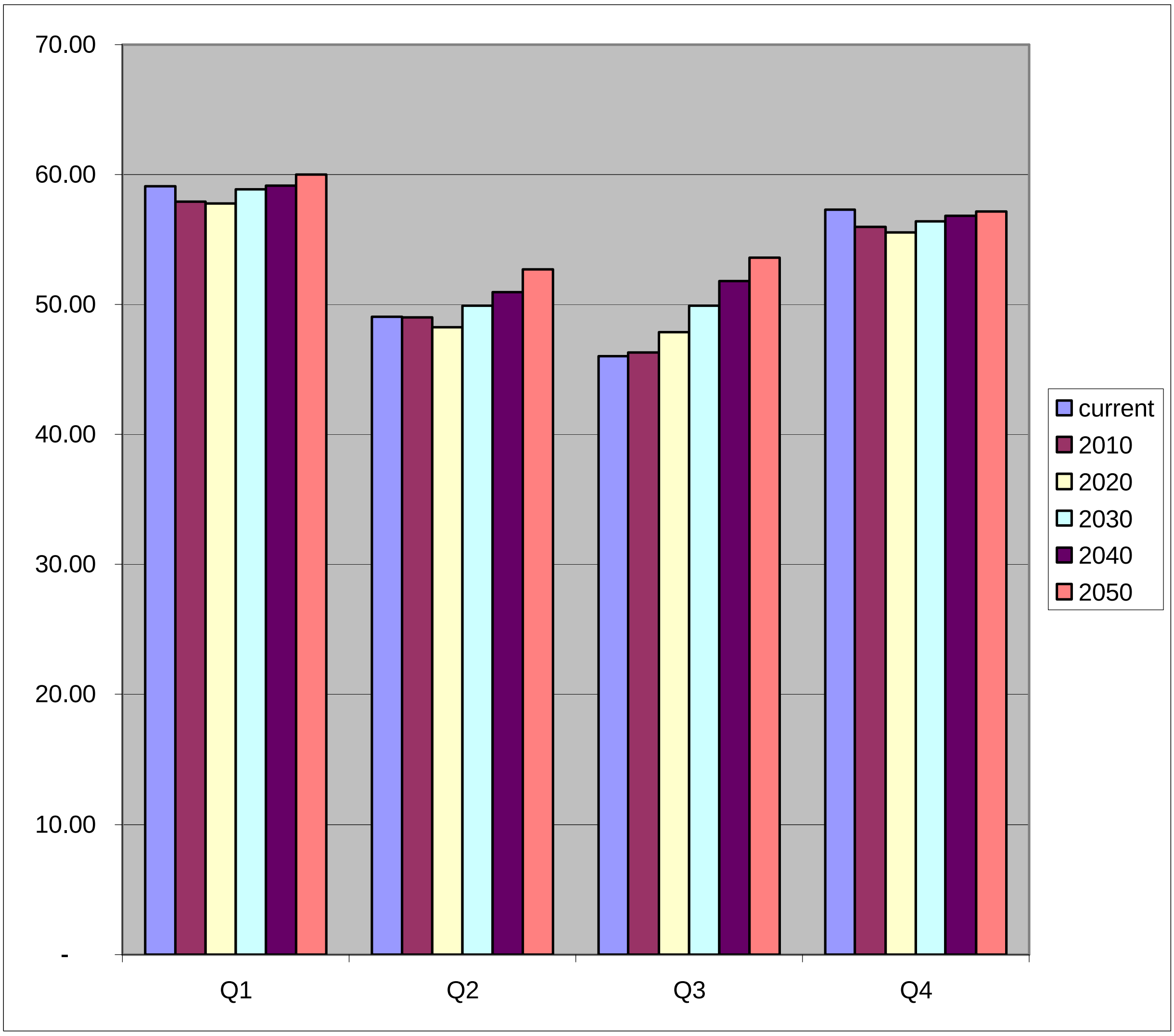


Figure 54: Quarterly Peak Electricity Demand (GW) for the Maximum onsite generation and heat pumps Scenario

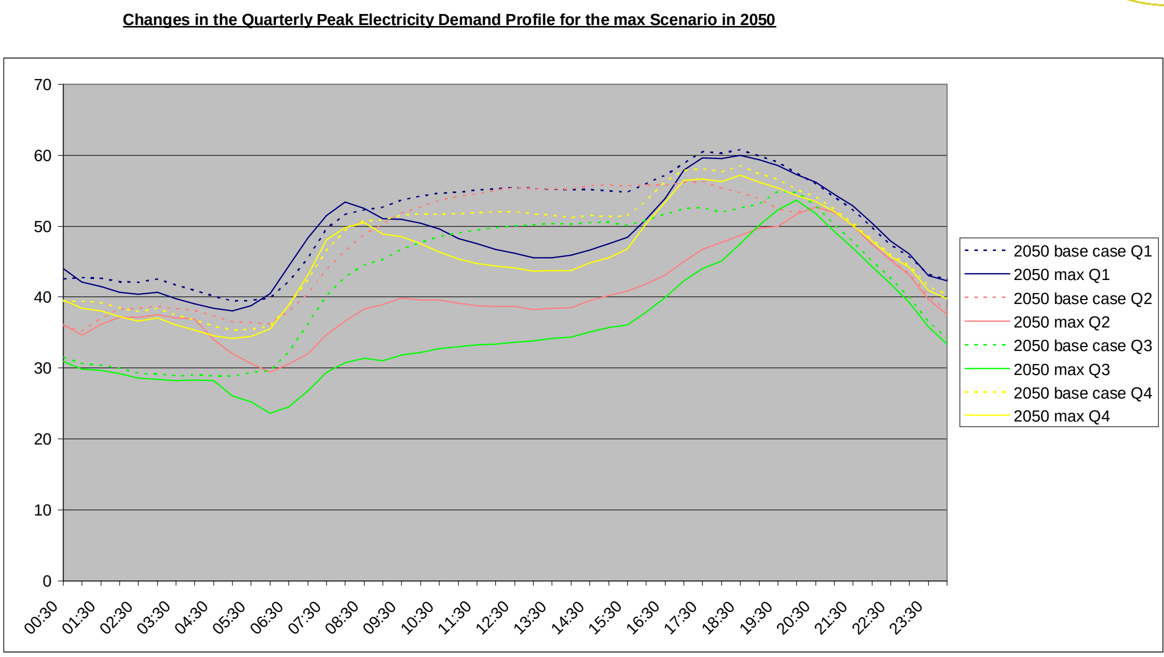


Figure 55: Quarterly Electricity Demand (GW) for the Maximum onsite generation and heat pumps Scenario

In this scenario installation of high levels of onsite wind and PV electricity generation and of heat pumps leads to a 10% decrease in the annual demand for electricity, but only a 1% decrease in peak demand, which occurs in Q1. This is because the increased demand from heat pumps is just a little larger than the electricity generated from onsite wind at the peak (PV generation will not contribute as the peak occurs in the early evening). As with the heat pumps only scenario, the morning and evening peaks in Q1 and Q4 occur at the same time of day, but are more pronounced.

8.6 High Growth cooling

Quarterly Peak Electricity Demand for high growth cooling Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	50.43	47.59	55.98
2020	57.85	53.73	50.91	55.65
2030	59.20	59.02	55.40	56.81
2040	59.51	65.23	60.51	57.49
2050	60.76	72.95	66.65	58.53

Time of Quarterly Peak Electricity Demand for high growth cooling Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	15:00	20:00	18:30
2030	18:30	15:00	19:30	18:30
2040	18:30	15:00	19:30	18:30
2050	18:30	15:00	19:30	18:30

Figure 56: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the High Growth Cooling Scenario

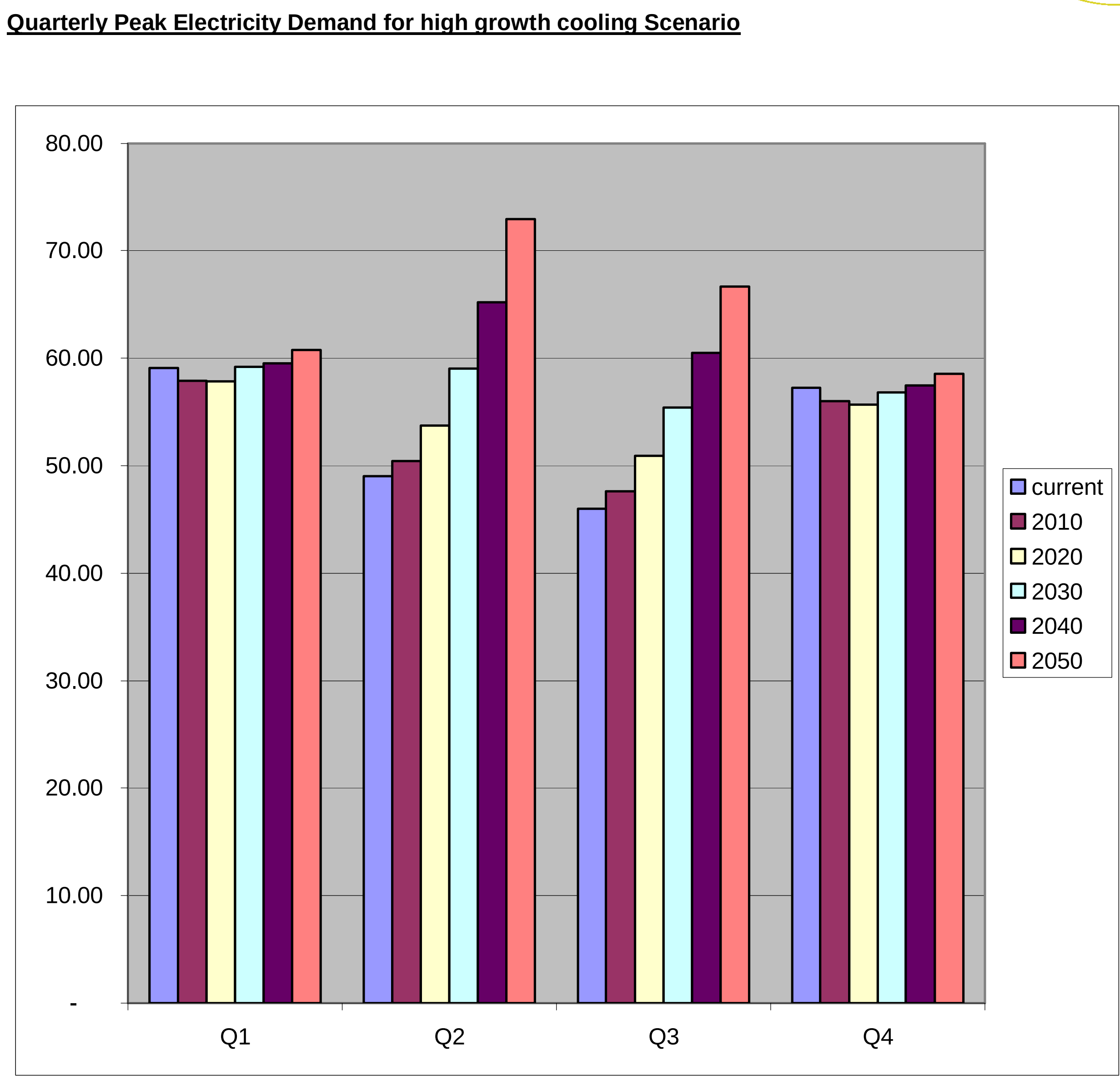


Figure 57: Quarterly Peak Electricity Demand (GW) for High Growth Cooling Scenario

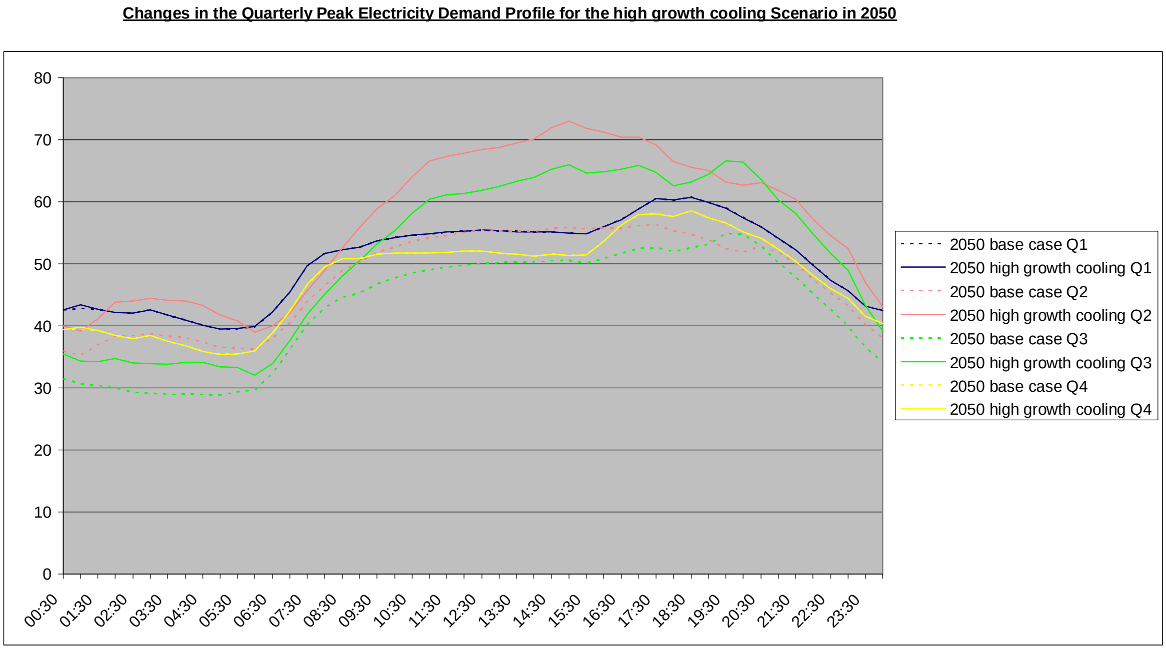


Figure 58: Quarterly Electricity Demand (GW) for High Growth Cooling Scenario

The high growth cooling scenario shows how increased demand for cooling in both the domestic and non-domestic sectors could substantially change the demand pattern for electricity in the UK. Here the peak demand mover from the winter quarters to the summer, and results in a 9% increase in the annual electricity demand, but a 20% increase in peak demand compared to the BAU scenario.

8.7 Limit cooling

Quarterly Peak Electricity Demand for limit cooling Scenario

	Q1	Q2	Q3	Q4
current	59.10	49.04	46.02	57.26
2010	57.88	48.28	45.65	55.98
2020	57.85	48.09	46.43	55.65
2030	59.20	48.73	47.62	56.81
2040	59.51	50.37	49.39	57.49
2050	60.76	52.46	51.39	58.53

Time of Quarterly Peak Electricity Demand for limit cooling Scenario

	Q1	Q2	Q3	Q4
current	18:00	12:30	19:30	17:30
2010	18:00	12:30	19:30	17:30
2020	18:30	12:30	20:00	18:30
2030	18:30	12:30	20:00	18:30
2040	18:30	17:30	19:30	18:30
2050	18:30	17:30	19:30	18:30

Figure 59: Quarterly Peak Electricity Demand (GW) and the Time at which this Peak Occurs for the Limit Cooling Scenario

Quarterly Peak Electricity Demand for limit cooling Scenario

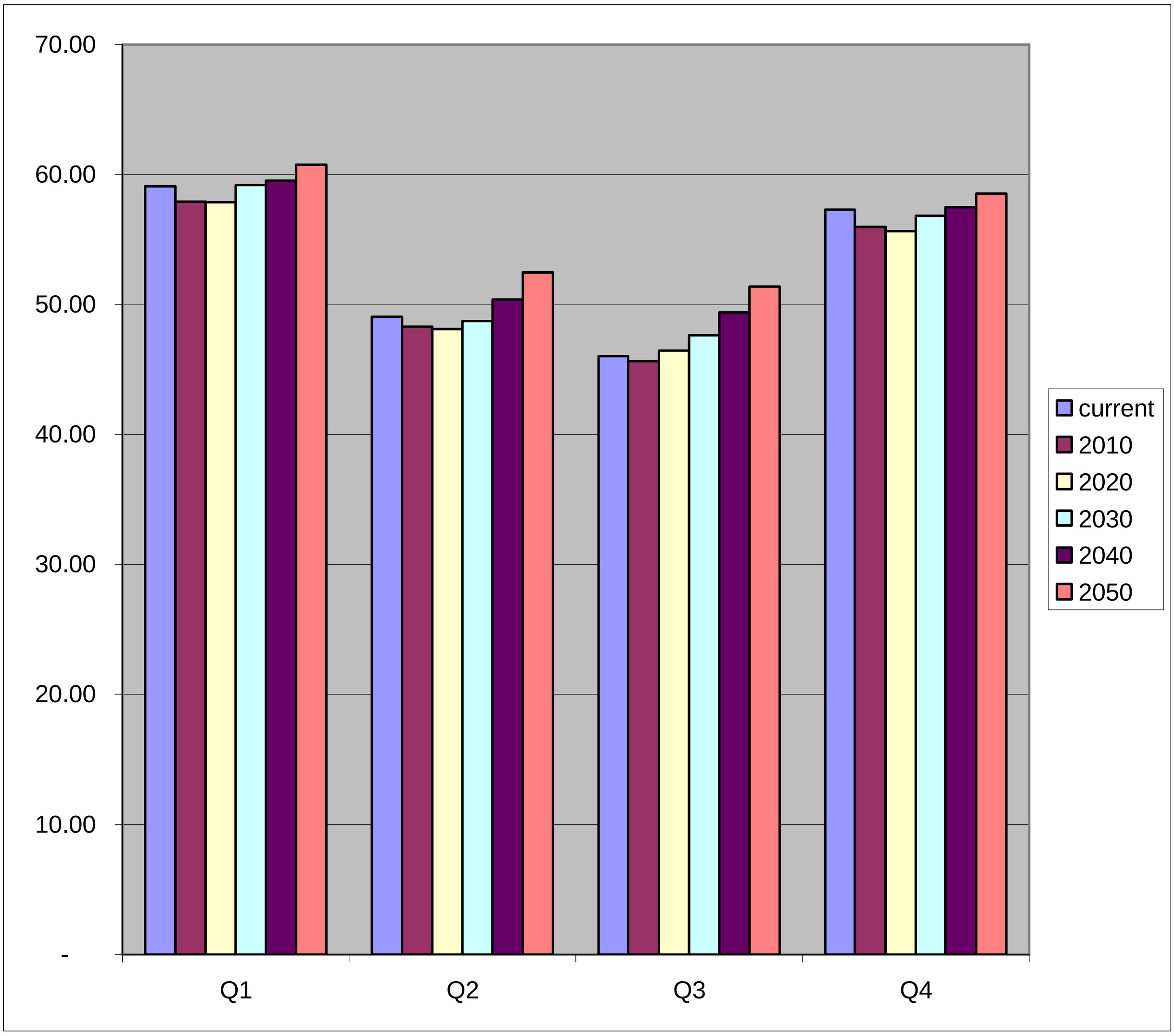


Figure 60: Quarterly Peak Electricity Demand (GW) for Limit Cooling Scenario

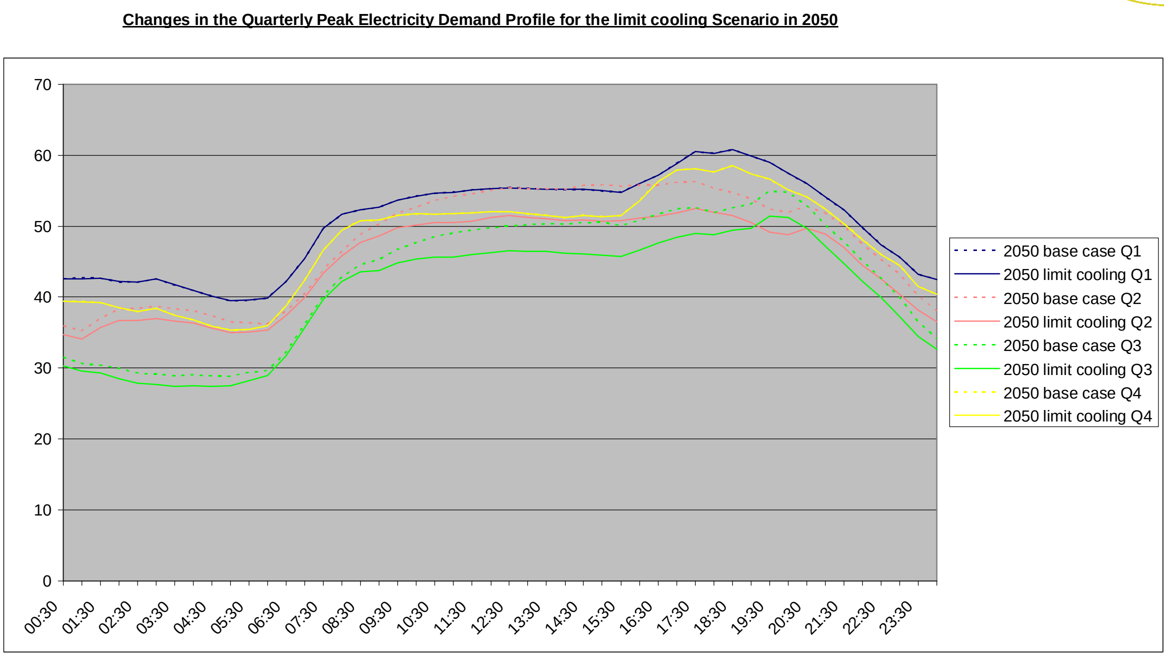


Figure 61: Quarterly Electricity Demand (GW) for the Limit Cooling Scenario

This scenario which limits the growth of demand for cooling results in a 2% decrease in the annual demand for cooling, but has no impact on peak demand which occurs in the winter.

9 Identification of Additional Data Sources

This section identifies additional data sources which it has not been possible to access for this study, but which could be used to improve upon the disaggregated use profiles in the future.

9.1 Additional Data Sources Identified

9.1.1 Monitoring studies carried out under the Carbon Visions programme

As part of the Carbon Visions research programme, several monitoring studies are being carried out mostly relating to housing. These include a longitudinal study of the Milton Keynes energy park, which has baseline data from 103 low energy homes constructed in the late 1980's. These studies have shown that larger dwellings with higher household incomes were responsible for most of the increase in energy use. Data is being collected from 33 of these homes including recording internal temperatures, relative humidity and lighting levels using 10 loggers per house together with monthly meter readings and householder interviews. Similar studies are also being carried on 61 other homes in Milton Keynes. In the midlands, electricity monitoring data from 72 homes have been collected at five minute intervals over a two year period.

At the moment this data is still being analysed but it should be is likely to be available later this year.

9.1.2 Study of household load patterns

Although this study[10] was carried out in Sweden, there may be some useful information on household electricity loads. The study looked at ten households with electric space heating and looked at when the household electrical peaks occurred and which end uses were consuming electricity at those points in time.

9.1.3 MTP Study "Monitoring Home Computers"

This study used data loggers on PCs[11] in 80 households in the UK to monitor consumption in different modes and to examine patterns of behaviour. We understand that the raw data could be used to assess the average daily consumption patterns on a half hourly basis; however the consumption data was recorded every minute for 15 days for all 80 households and therefore there is a vast amount of data to be processed. Despite this, given the paucity of data in this area and the general feeling that consumer electronics are using increasing amounts of energy in our homes, this would be a worthwhile exercise. We would need to obtain permission from the MTP/SPM team at DEFRA to use this data.

9.1.4 Carbon Trust Advanced Metering Trial (2004-2006)

This provides half hourly gas, electricity and water consumption for small and medium-sized enterprises gathered during the Carbon Trust's "Advanced Metering for SMEs" project (2004-2006). The data was collected from a portfolio of sites by seven independent metering contractors. Sites are characterised by the number of employees, the geographical location, and geographical region. This data is expected to be made available via the UK Energy Research Centre's Energy Data Centre[x].

9.1.5 Electricity metering data at the local level

BERR have produced annual electricity consumption data using electricity metering data at the middle layer super output area, which typically comprises electricity consumption equivalent to around 2000 households[y]. If this data were made available on a half hourly basis and ideally, at more disaggregated level, such as postcode, it would be possible to gain a far better understanding of the different electricity demand patterns associated with different types of buildings and industrial sectors. This would greatly increase the robustness of the end user demand estimates that could be produced.

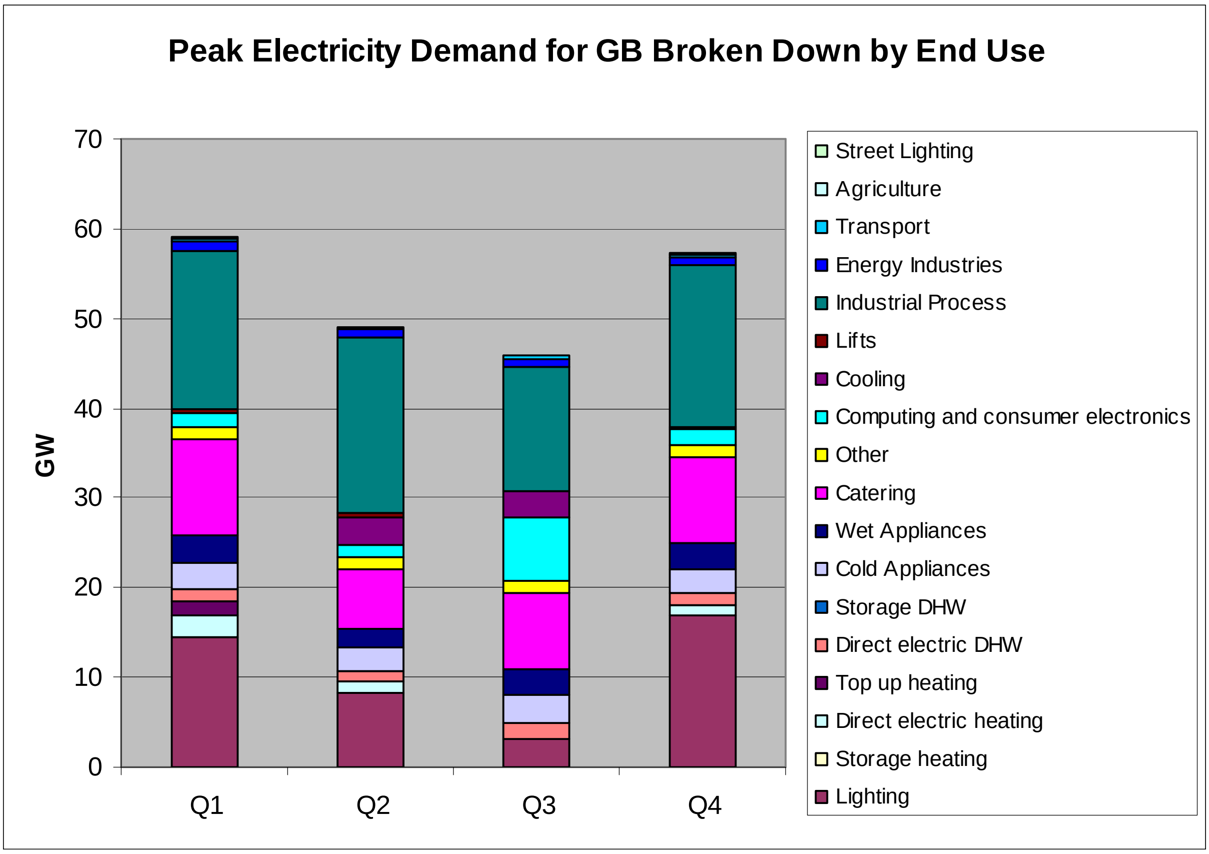
9.2 Additional Monitoring

In addition to the data sources identified above it is clear that there is also a need for additional monitoring studies at the end use level. Without a clear understanding of the current patterns of electricity demand it will not be possible to assess accurately the contributions made to peak demand, and hence the potential that exists for reducing demand.

[x] http://ukedc.rl.ac.uk/EDC_data_buildings.html
[y] http://www.berr.gov.uk/files/file40044.pdf

Conclusion and recommendations

This study of peak electricity demand in Great Britain, using readily available data sources, has updated our understanding of the end uses of electricity that contribute to current peak demand across the different seasons. Revised end user demand profiles were built up from sectoral and end user demand profiles from existing data sources which were then reconciled to half hourly demand for Great Britain from National Grid data. The resultant estimates of the end use breakdown of peak electricity demand for each quarter are shown below:



This shows that lighting, catering, consumer electronics and, in the summer quarters cooling demand are the building end uses which make the biggest contributions and which therefore have the biggest potential for demand reduction given suitable technologies.

A number of additional data sources were identified that could be used to improve our understanding of the constituents of peak electricity demand. In particular;

- Monitoring studies carried out under the Carbon Visions programme

- MTP Study “Monitoring Home Computers”
- Carbon Trust Advanced Metering Trial (2004-2006)
- Electricity metering data at the local level

In addition to the data sources identified above it is clear that there is also a need for additional monitoring studies at the end use level. Without a clear understanding of the current patterns of electricity demand it will not be possible to assess accurately the contributions made to peak demand, and hence the potential that exists for reducing demand. More monitoring data would also help to address the unresolved issue of high night time electricity demand, which although not necessarily relevant for looking at peak demand, has significant CO_2 implications.

Having established the current components of peak electricity demand (based on available data sources), a spreadsheet model was developed to explore how size and position of the peaks might change in the future. Although electricity consumption in the UK has been rising over past decades, in more recent years demand has levelled off somewhat. To explore the impact of technology changes a “Business as Usual” scenario, which includes the impact of expected changes in energy efficiency and demand, was first developed. In the “Business as Usual” scenario there is a slight increase in peak demand in both Q1 and Q4, with only minor changes to the shape of the daily demand profile. Whereas in Q2 and Q3 a significant increase in daytime demand is expected due primarily to increased demand for cooling and computers and consumer electronics. The BAU scenario indicates that the time at which peak demand occurs in Q2 is shifting from the late morning to the afternoon, but no shift in the timing is evident in Q1, Q3 or Q4.

For lighting, the “Business as Usual” scenario already assumes significant improvements in energy efficiency through the deployment of newer technologies. It is clearly important to ensure that more efficient lighting technologies are employed in the future otherwise peak demand will be higher than suggested here, particularly in the winter quarters. During the summer quarters increased demand for cooling and computing and consumer electronics are responsible for much of the predicted increase in demand. For both these end uses it is largely changes in end user demand rather than energy efficiency improvements that dominate.

Seven other scenarios were developed to look at the impact of increased levels of onsite electricity generation, wider deployment of heat pumps and different demands for cooling. The renewable generation scenarios indicate that, even when significant levels of onsite renewable electricity generation are deployed, although they may lead to a noticeable reduction in the annual demand, they do not necessarily impact on peak demand. The modelling also showed that if heat pumps increasingly replace boilers for providing space heating and hot water, then peak demand could increase significantly. Similarly, if demand for space cooling increases faster than anticipated then peak demand could shift to Q2 and Q3. Other scenarios that were modelled are a zero carbon new build scenario, which represents the levels of onsite electricity generation and heat pumps that a zero carbon new build policy might prompt, a scenario which looks at the combined impact of the onsite wind, onsite PV and heat pumps scenarios, and a scenario where the increase in cooling demand is limited. The results of the scenario modelling for 2050 is summarised in the following table.

Scenario	Peak Demand		Annual GWh
	GW	% Change	% Change
"Business as Usual"	60.76	-	-
Onsite Wind Generation	59.1	-3%	-3%
Onsite PV Generation	60.76	-	-9%
Heat Pumps	62.08	2%	2%
High Growth Cooling	72.95	20%	9%
Zero Carbon New Build	60.54	-0.4%	-3%
Onsite Generation and Heat Pumps	60.01	-1%	-10%
Limit Cooing	60.76	-	-3%

These scenarios are simplistic representations which require further work to refine and expand them and provide a better understanding of how peak electricity demand may change in the future. In particular,

- to assess the extent to which installation of on-site renewable electricity generation and heat pumps is feasible and the ability of the market to meet the demand,
- to explore how different operational hours, replacement of existing electric heating systems and the use of heat pumps to supply hot water would impact on demand, and
- to develop more detailed cooling scenarios that consider the combined impacts of increased consumer demand, technology change and the likely impact of climate change

In the modelling study, carbon emissions were also calculated assuming an average annual grid electricity emissions factor of 0.537 $kgCO_2/kWh$ (the current 5 year rolling average emission factor given in DEFRA company reporting guidelines[z]) applies across all years. Clearly the actual carbon emissions will vary in the short term, depending on both the mix of plant available and their relative operation costs, and in the longer term plant built to meet the demand. Whilst the model is set up so that is possible to explore how changes in the future carbon intensities for grid electricity will impact on overall (and marginal) carbon emissions for the various scenarios, this has not been explored here. Further modelling work would be necessary to study the interactions between increased onsite electricity generation and the carbon intensity of grid electricity.

[z] DEFRA company reporting guidelines

References

[1] Pout, C and Hitchin, R, Potential for Reducing Peak Electricity Demand from Buildings, BRE Report to Defra, 2006.

[2] BERR, Digest of UK Energy Statistics, 2007.

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[4] Boardman, B., Home Truths: A Low Carbon Strategy to Reduce UK Housing Emissions by 80% by 2050, ECI, 2007.

[5] http://www.nationalgrid.com/uk/Electricity/SYS/

[6] http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data/

[7] Elexon, Load profiles and their use in electricity settlement.

[8] Electricity Association and BRE, Domestic lighting in the UK: An analysis of electricity usage, 1998.

[9] http://www.esru.strath.ac.uk/EandE/Web_sites/06-07/Carbon_neutral/case_study_folder/case%20study_.htm

[10] Sernhed, K, What's on the top? Household patterns and peak load problems, Lund University, Department of Energy Sciences, 2006.

[11] MTP, Monitoring Home Computers, RPICT01/06, 2006 - http://www.mtprog.com/ReferenceLibrary/RPICT01_06_Use_of_home_PCs_FINAL.pdf