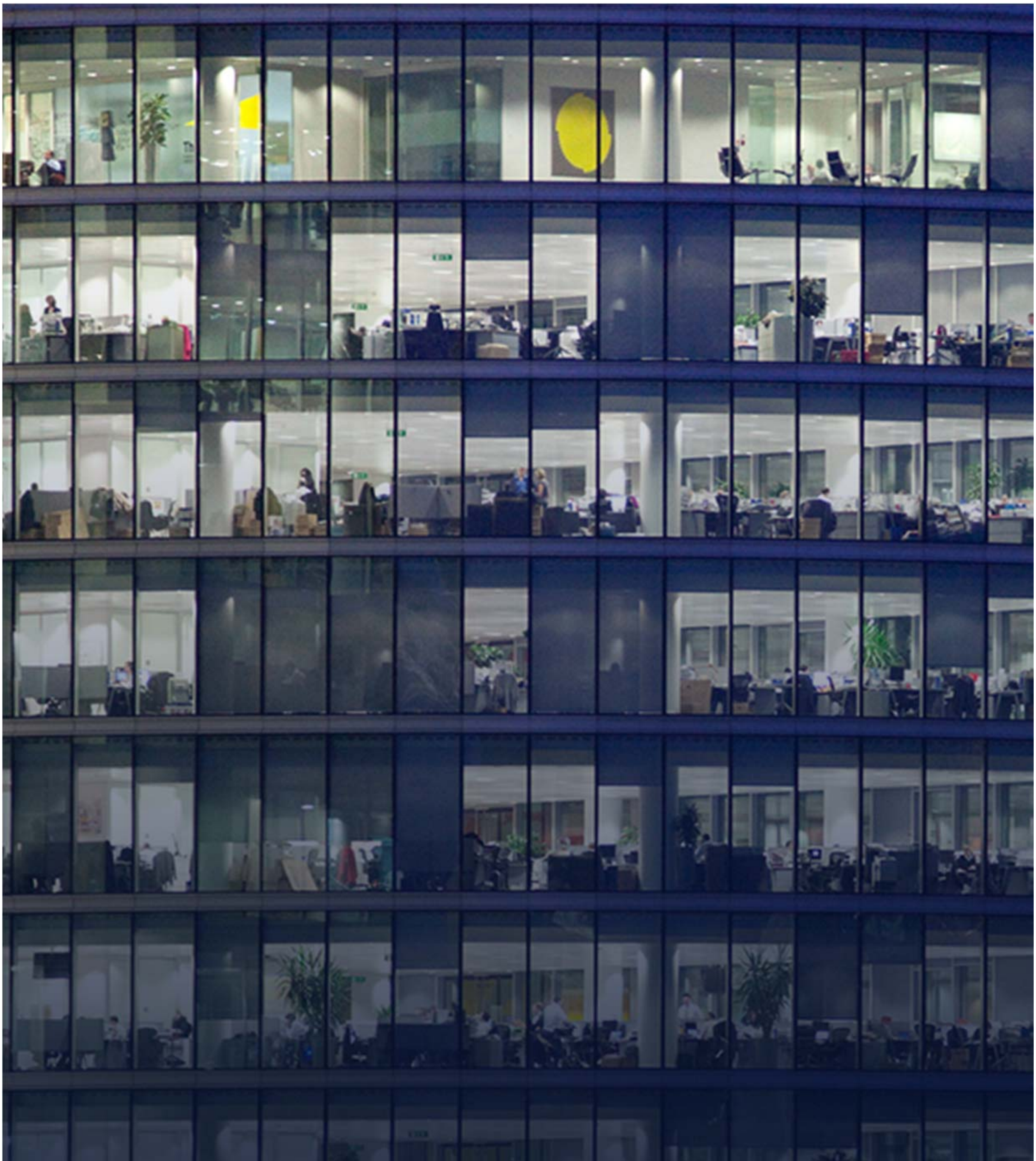

KEEPING THE LIGHTS ON

The role of a rapid switch to LEDs in reducing peak winter demand in the UK

GREENPEACE

Photo: Steve Morgan / Greenpeace

Author: Chris Goodall, Carbon Commentary

Carbon Commentary is a web site where Chris writes about the many options the world can use to move away from fossil fuels. It covers energy generation and efficiency both from technical and policy perspectives.

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Contents

Executive summary

Demand

- Lighting is responsible for about 20% of total UK electricity demand and about 29% of peak winter need.
- On the average winter day, lighting demand varies between about 4 GW in the middle of the night and 15 GW at about 5.30pm.
- A move to near-100% LED lighting across business and public sector, domestic homes and street lighting would reduce peak winter demand from about 52 GW (based on winter 2015/17) to just over 44 GW.
- With reasonable assumptions, such a transition would almost certainly enable the UK for example to avoid blackouts even after the last coal power station is closed/mothballed.
- Even a partial switch (reducing electricity demand by half the maximum reduction) would cut peak demand by almost 4 GW

Paybacks

- Savings from switching entirely to LED in homes will save about 2.7 GW of peak winter demand. Street lighting will save a further 0.5 GW and the UK might save about 4.5 GW of peak demand from switching non-domestic, non-street lighting bulbs.
- The large majority of the **domestic** saving comes from switching halogen bulbs to LEDs. (There is an approximately 5:1 ratio in light output to electricity consumed but actual savings can be greater). At current light output per watt LEDs offer greater efficiency than CFLs but the difference is not huge. However LEDs will continue to improve, perhaps quickly.
- In industrial and office use, the savings to users will partly come from much longer replacement cycles and from the ability to dim LEDs when not needed, unlike other efficient lamps in widespread use.
- An approximate payback period from switching the most used bulbs in the typical domestic house to LED is about 2 years at current prices. An expenditure of £62 on replacing about 21 of the bulbs in living areas would cut annual electricity bills by at least £24.
- According to claims made by a leading installer in non-domestic locationsaverage claimed payback period on electricity use in commercial installations is about 16 months. Allowing for exaggeration, perhaps the figure is probably about 2 years. Including the value of lower maintenance costs and better light levels would substantially reduce this length of time.

Why isn't the switch happening faster?

- Householders are not aware of how easy and cheap the transition could be. LEDs are seen as expensive, quirky and troublesome. The light is sometimes seen as unattractive, although current 'warm white' bulbs offers a similar spectrum of light as a traditional bulb. The scope for improving public knowledge rapidly is enormous.

- Commercial buildings sometimes suffer from the owner/tenant split. More generally, management is worried by the disruption caused by lighting changes; sometimes large numbers of luminaires need to be replaced, automatic dimmers and PIRs adding to the cost
- The efficacies of LEDs are not yet hugely better than fluorescent, sodium or discharge lamps. This isn't the whole story because LEDs are better at putting a broad spectrum of light onto the place where it is needed but convincing companies and government will take time. In addition, the speed of LED improvement and the pace of cost reduction is so fast that there is some genuine logic in waiting.

Conclusion

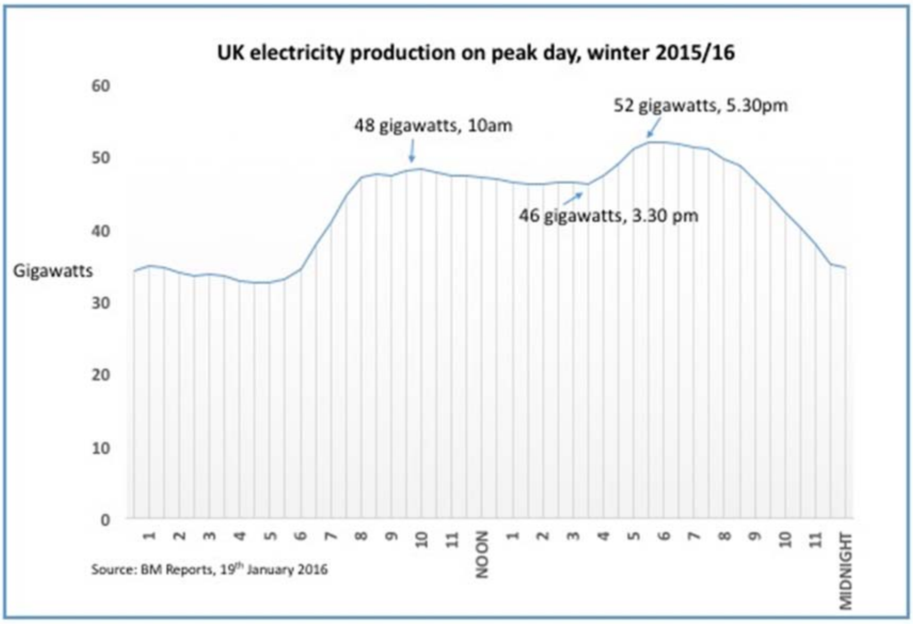
- LED conversion can make a real difference to peak demand. Full switching might cut electricity use by up to 8 gigawatts. A more realistic target might be to attempt to reduce power need by over 3.2 gigawatts within 3 years. 3.2 gigawatts is the maximum output of Hinkley Point C.

Chapter 1: Putting a scale on the challenge

Electricity margins in the UK are expected to become tighter in the near future. With many of the UK's ageing generation capacity closing/expected to close and valid questions raised concerning the certainty of new capacity coming online in the near future this chapter looks ahead to how capacity margins could develop over the next decade.

- Electricity demand is highest at around 5.00-5.30 pm on cold weekday evenings in December and January. The chart below shows the profile of power generation over the course of 19th January 2016, the day during which the highest peak electricity requirement was seen last winter.
- The graph demonstrates three important features. First, there is a morning peak, occurring at around 9 am. On the day shown, electricity generation hit 48 GW at this time. Demand then gradually falls until around 3.30 pm to about 46 GW. Then we see a sharp upward swing, taking the total generation to about 52 GW around 5.30pm. From that point, electricity need falls.

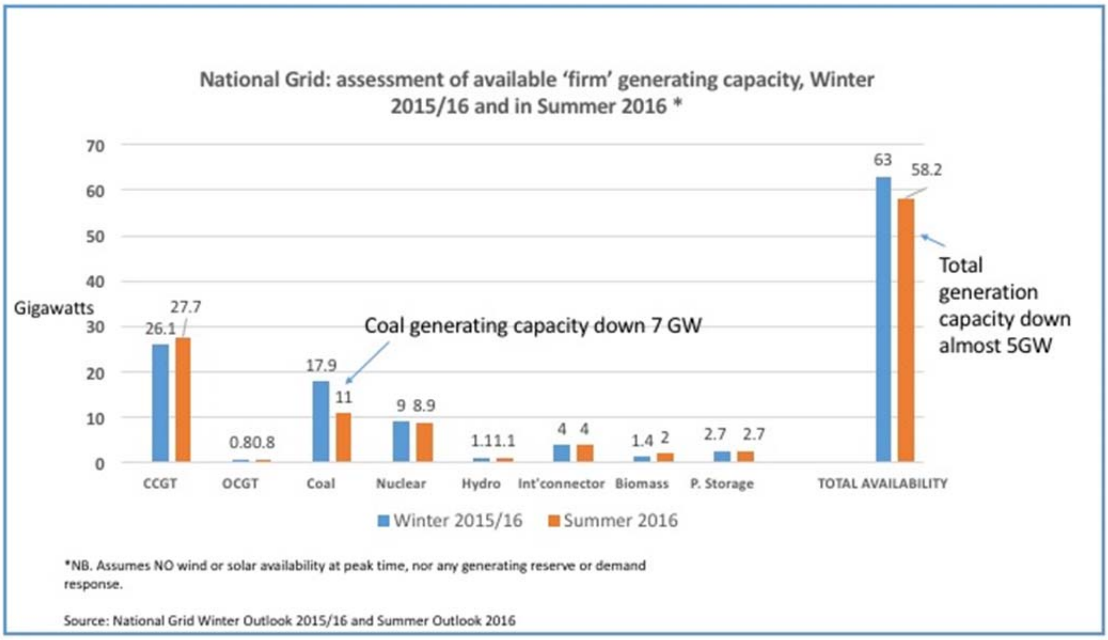
Chart 7



- The closure of coal-fired power stations, and the lack of any large-scale replacement by other non-intermittent sources of power, has resulted in a fall in the amount of peak energy generating capacity in the UK.
- Within a few years, coal generation may have disappeared completely from the electricity grid. Possibly excepting the remaining coal boilers at Drax, this may be as early as 2018. At this point, some commentators predict, the UK may experience short winter blackouts. This will happen because the available generating capacity will not be able to meet the maximum demand on weekday evenings in December and January, if the wind is not blowing sufficiently strongly to cover the gap.

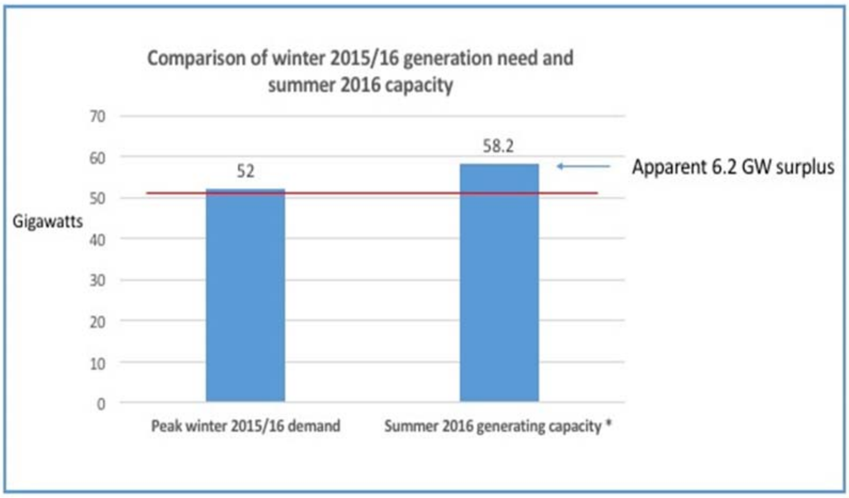
- This may well be too pessimistic a prediction. 'Demand management' (the manipulation of demand to fit the available supply of electricity) is becoming increasingly effective. Unused spare generating capacity – usually powered by diesel and therefore highly polluting – is readily available for the National Grid to call upon. However, even with these buffers, electricity disruptions are still possible.
- If this happens, it is nearly inevitable that the lack of reliability of wind power will be blamed for the short blackouts that will occur. Lighting is a large fraction of total electricity demand at peak winter times. To help avoid the problem of insufficient power generating capacity, a more rapid switch to LEDs may make very good sense.
- The nature of the problem can be seen from looking at National Grid's forecast for the available UK generating capacity in mid 2016. The chart below compares the Grid's figures for winter 2015/16 and those of its formal prediction for summer 2016-04-17

Chart 8



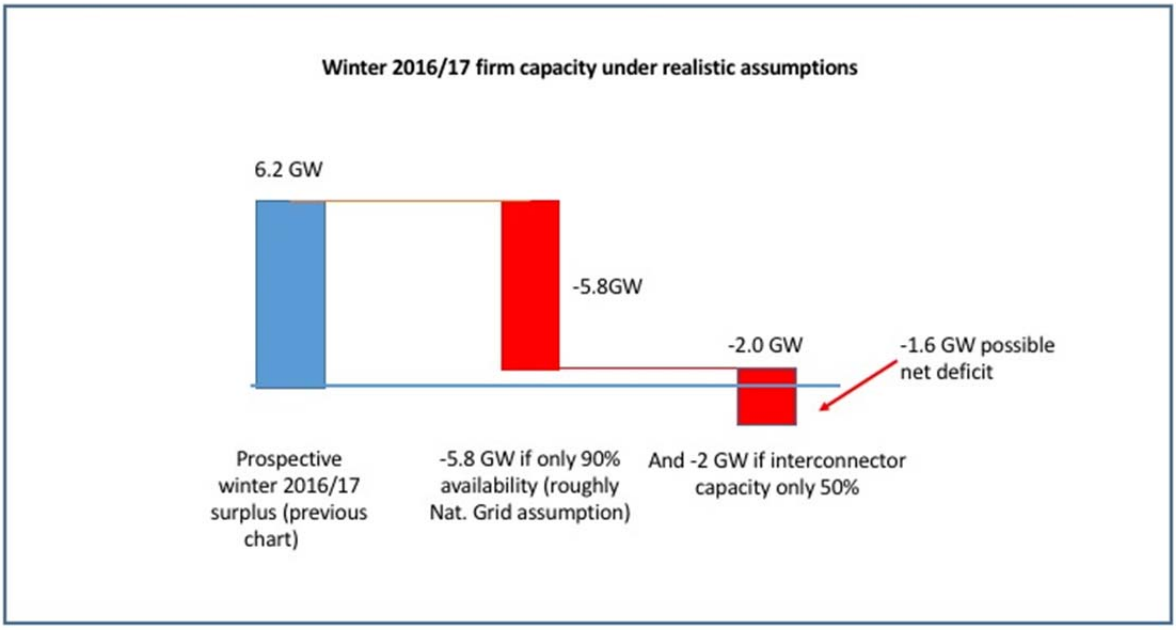
- Chart 8 shows the major reduction in capacity arising between last winter and this summer arising because of the loss of coal stations. Nevertheless, 'firm' generating capacity is still greater than last winter's peak demand.

Chart 9



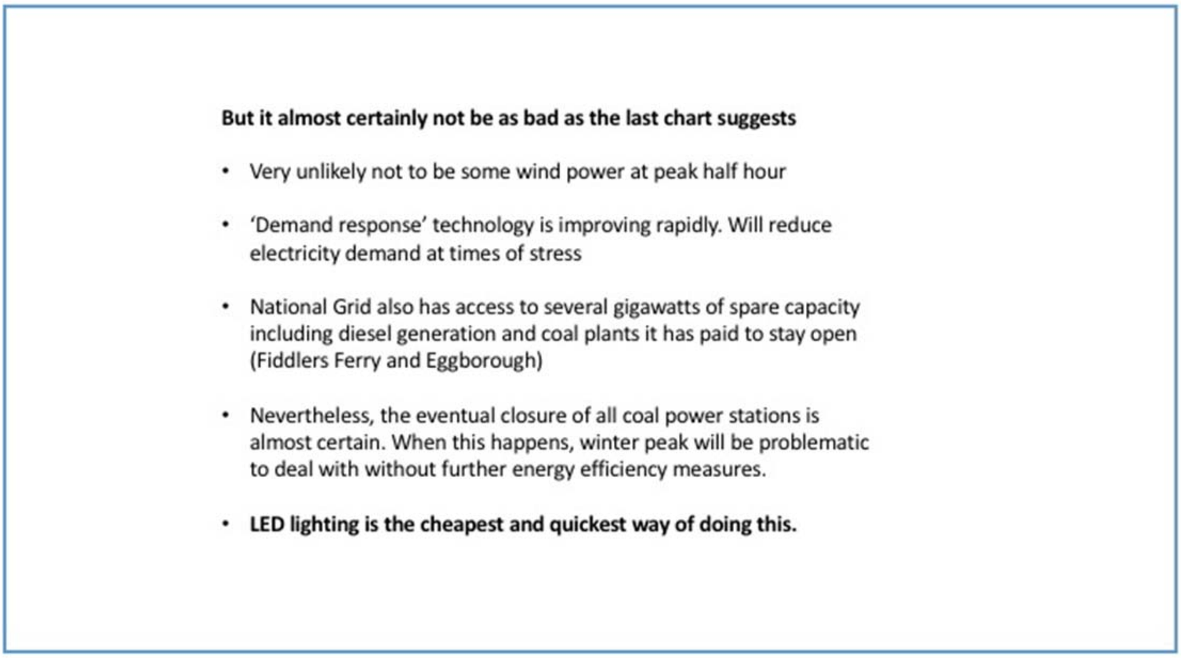
- Chart 9 is too optimistic a picture because it ignores the likelihood of major power stations being unavailable because of maintenance or repair needs. Similarly it assumes that all the UK's total interconnector capacity is available for importing power from France, the Netherlands and Ireland. This is unlikely, because when the wind is not blowing, and therefore winter power supplies are short, Ireland is also likely to want extra electricity from the UK. The flow across the two Irish interconnectors is likely to be westward. This would reduce the underlying interconnector capacity to around 2 GW.
- The net impact of a 90% availability and 2 GW interconnector flow assumption is shown in Chart 10.

Chart 10



- However other factors work in the opposite direction, meaning that a serious problem is unlikely this year.

Chart 11



- However when the 11 GW of remaining coal capacity included in the National Grid's Summer 2016 Outlook eventually closes the problem will become severe. Without any coal capacity, and no new CCGT, biomass or hydro, total firm generating capacity will fall to 47.2 GW, even at 100% uptime and full interconnector flows. This is almost 5 GW less than peak demand over last winter. Demand response is unlikely to be able to cover this within the next few years.

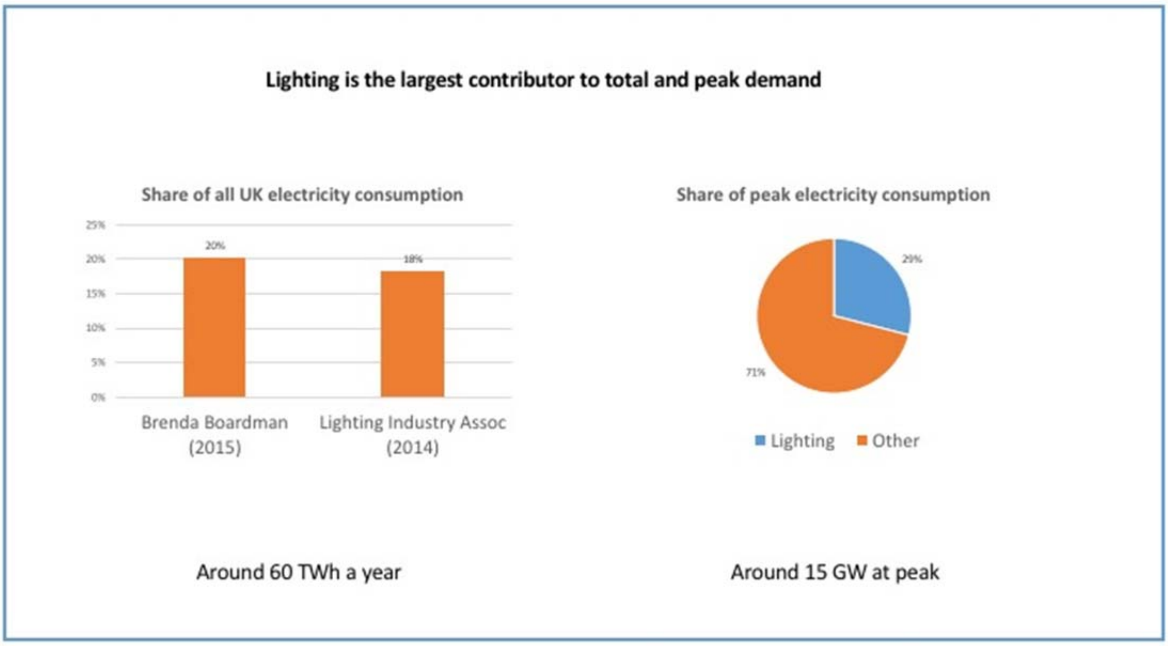
Chapter 2: switching to LEDs will lead to significant electricity savings

Lighting makes up a large fraction of total electricity demand during peak winter times. This chapter sets out how the UK might be able to reduce peak winter demand by a total of about 7.7 GW by switching 100% to LEDs.

Overall lighting use

- Data is poor. This is for two principal reasons. First, lighting demand is falling, possibly quite rapidly, and previous studies are out of date. The last proper survey of domestic lighting demand is from 2010 and the amount of electricity used is now lower as a result of the continuing switch into CFLs. Second, it is expensive and complex to measure the amount of electricity used by lights. They are often on the same circuit as many other pieces of equipment. So, for example, there are studies of electricity use for 'small power' applications in public buildings such as hospitals. But this data mixes computers, lights, fridges and other electric appliances.
- The most useful and productive information I have found is an article by energy efficiency specialist Dr Brenda Boardman from the Environmental Change Institute of Oxford University.[1] This report extensively refers to this paper and also the sources that Brenda Boardman used in her work.
- The total amount of electricity used for lighting is about 58-60 terawatt hours a year, or about 20% of total consumption. Lighting is more important at peak time in the early evening because lights are in businesses, other buildings, homes and in streets. Brenda Boardman thinks that about 29% of 5.30pm power demand comes from lights.

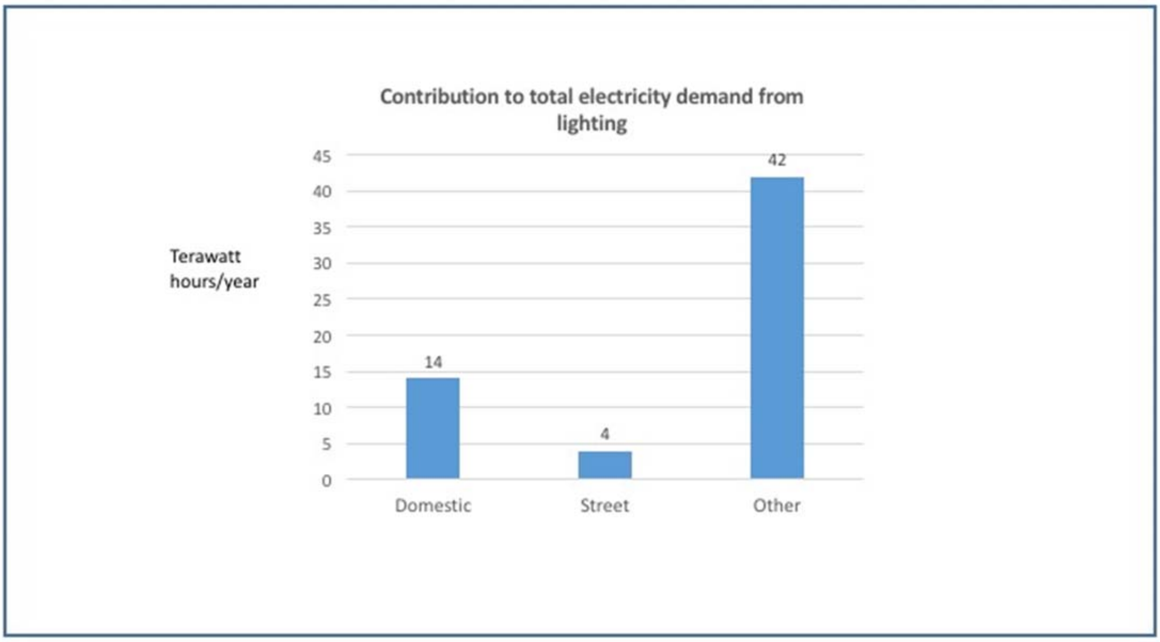
Chart 12



[1] *Low-energy lights will keep the lights on.* Brenda Boardman, Carbon Management, 2014.

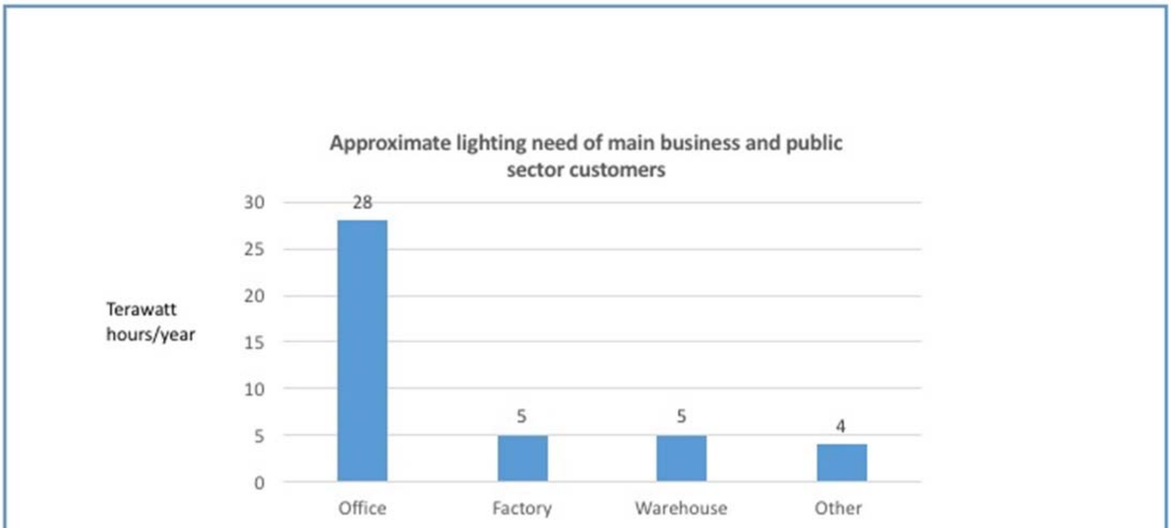
- Total yearly lighting demand is dominated by non-domestic use. Domestic use represents slightly less than a quarter of electricity use. Street lighting is less than 10% other applications are slightly more than two thirds. This includes private business and public services.

Chart 13



- Estimates of how much electricity is used by various commercial and public sector users are of poor quality. However, all sources agree that public and private sector offices represent by far the largest use of power for lighting.

Chart 14

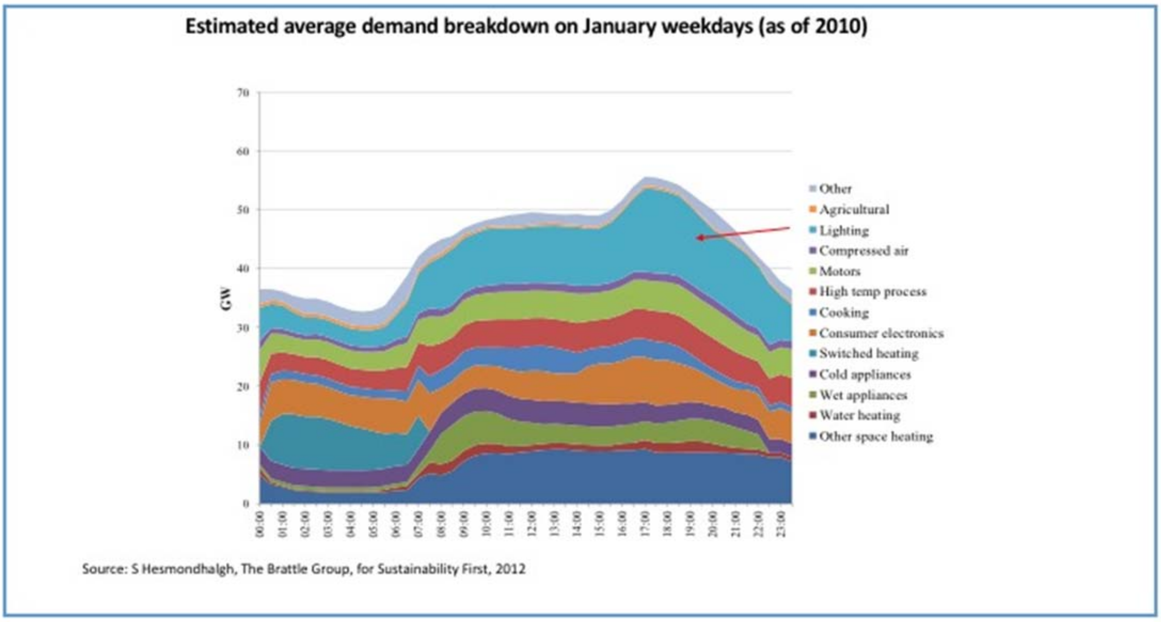


Source: Chris Goodall estimates from a variety of different original sources

- The amount of electricity being used for lighting varies throughout the 24 hour winter day but is usually the most important consumer of electricity, except in the early morning hours.

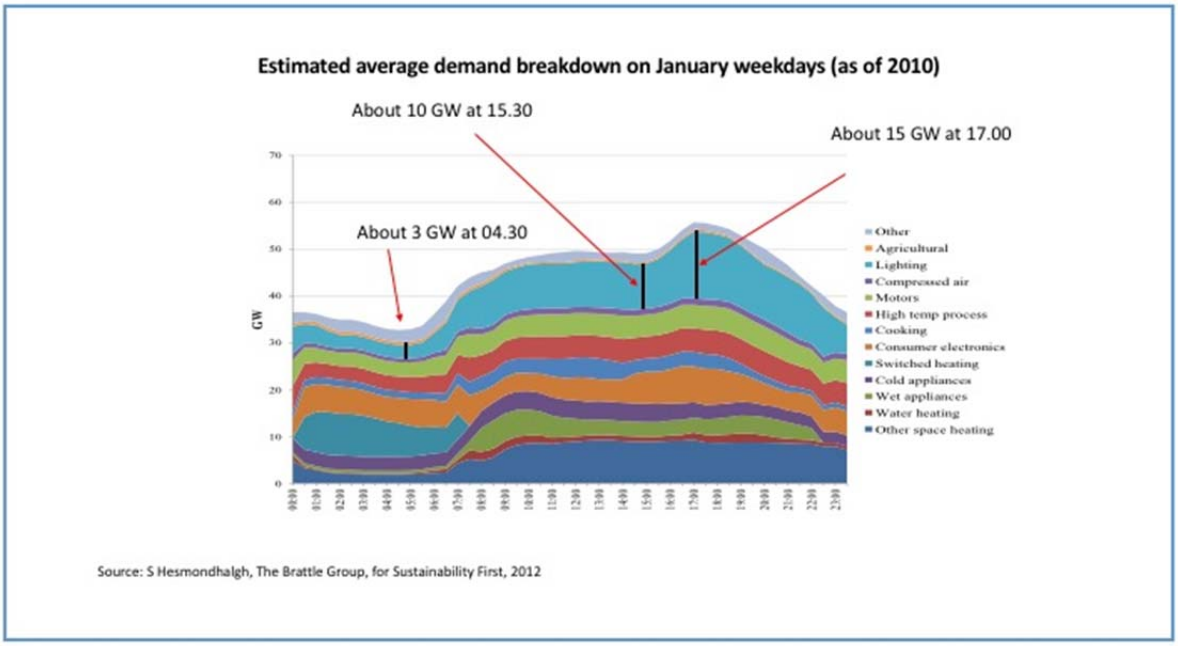
Use of lighting at winter peak

Chart 15



- The amount of electricity being consumed varies from about 3-4 GW in the early morning hours to around 15 GW at 5.30pm peak.

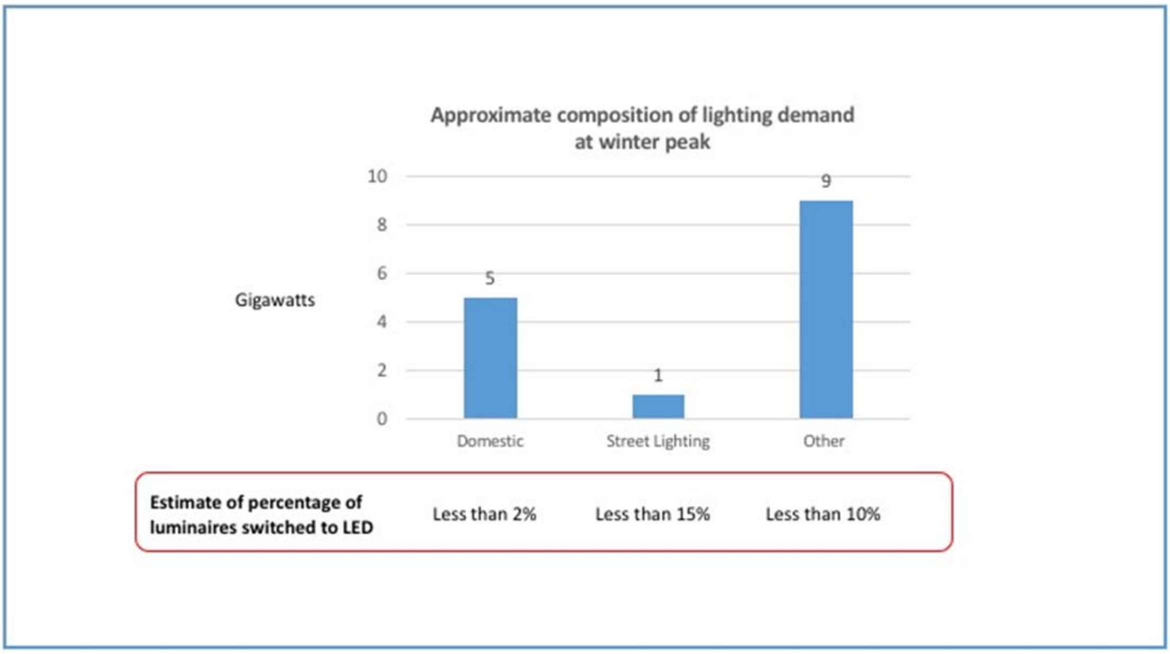
Chart 16



LED conversion levels: the current situation

- First, we need to estimate what percentage of all lamps are now powered by LEDs. As with many of the numbers in this report, accurate figures are very hard to come by. My best estimates are in the chart below.
- Although these shares are all small fractions of the total number of lamps, they do mean that we need to downgrade the potential savings slightly.
- The number of LEDs sold is rising very rapidly. However, replacements only tend to be made after a failure of a previous bulb. So although LEDs will eventually take over all lighting (possibly accompanied by Organic LEDs, or OLEDS,) the rate of natural transition will be quite slow. In domestic homes, for example, a 100% transition might well take 15 years if not pushed by government or other organisations.

Chart 17

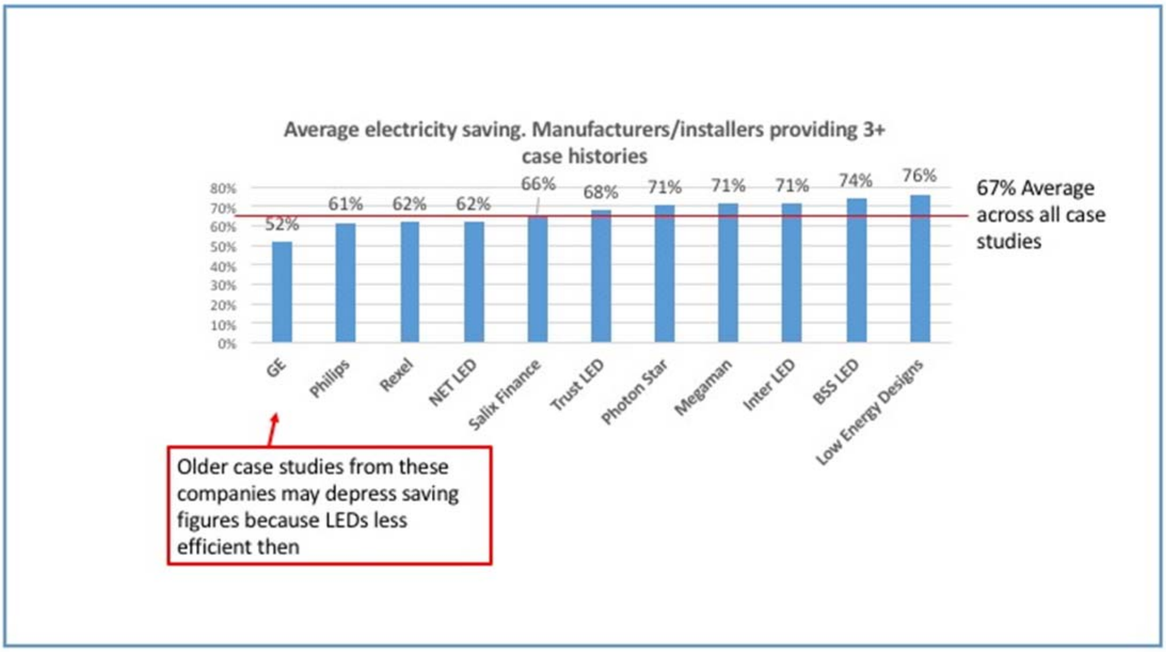


Non-domestic lighting, including street lighting

- As far as I can see, there is no fully researched estimate of the reduction in lighting demand that would come from a replacement of all non-LEDs in business and public sector.
- However many companies involved in the manufacture, sale and installation of lamps and luminaires do provide internet 'case studies' of the impact of a switch to LED among business and other users.

- These 'case studies' will probably exaggerate the percentage reduction in electricity use from the use of LEDs. Nevertheless, they will not be wildly inaccurate.
- I collected 100 separate and unrelated cases from web sites and other sources. These studies come from 17 different sources. The largest group (21 studies) can from TrustLED, a company based in the North East that surveys sites and installs appropriate LEDs. (The survey and specification requirements are not trivial. Philips has over 30,000 separate items in its lighting catalogue).
- In the chart below, the average results from all those providing 3 or more case studies are shown. As can be seen, the percentage reductions in electricity use are strongly grouped between 61% and 71%. The average electricity use reduction is 67%, or two thirds of previous consumption.

Chart 18

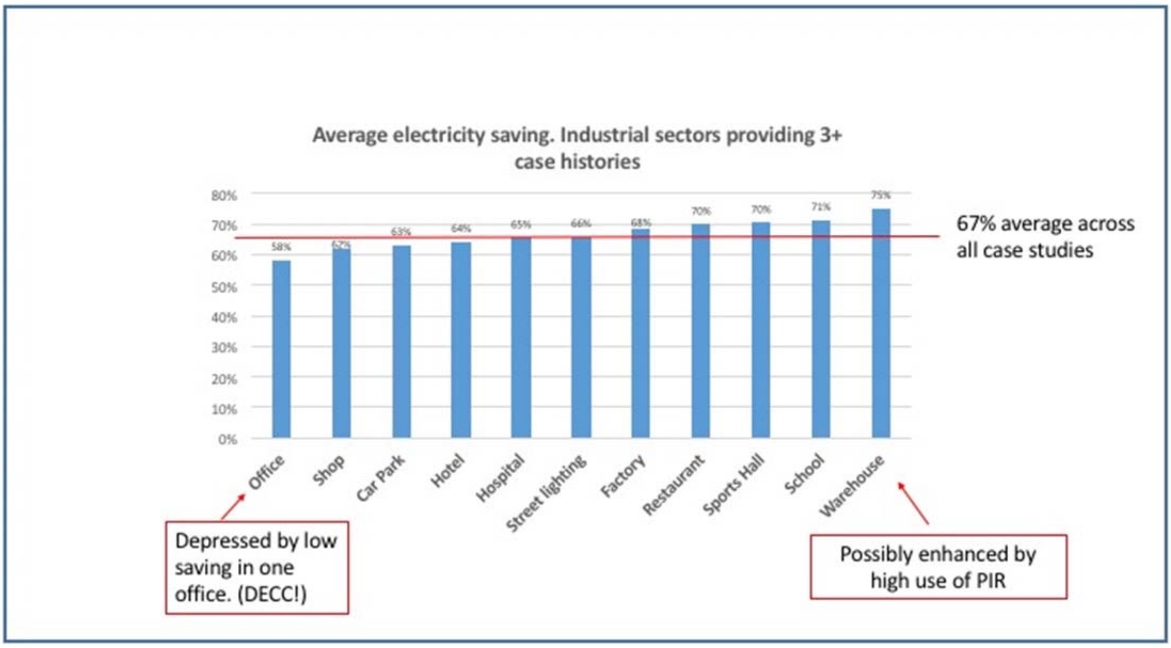


- It is vital to note that these figures are for non-domestic applications and that they do not simply arise because LED lamps are more efficient than alternatives. Much of the saving often comes from being able to switch LEDs on and off with ease and speed. Alternative bulbs, such as low pressure sodium will sometimes take more than 4 minutes to warm up. So in many applications these non-LED bulbs are never turned off. By contrast, LEDs can be turned on automatically when someone enters a room, for example. Or they can be easily dimmed when natural light levels are high.
- In several case studies, particularly for applications in sports halls, the light levels have been significantly increased. The stated reductions seem to be calculated after this 'rebound' effect.
- The average savings across different industrial sectors are also quite consistent.
- The greatest reductions come in warehouses (17 case studies) with cuts of three quarters of previous consumption. This will be because of the ability to install controls that turn off the lights when not needed.

Street-lighting.

- The Green Investment Bank and Salix Finance offer very cheap or zero-cost loans for councils to invest in LED street lighting. Local authorities are not required to invest their own capital.
- The advantages of LED lighting include lower maintenance costs and the ability to dim lights when no cars are on the road. Less light is dispersed upwards and outwards. LEDs probably produce safer roads because of the daylight colour of the light and its effect on visibility compared to sodium or other lamps.
- In the face of clear benefits and low cost finance, I do not know why councils are so slow to improve their street lighting. Sometimes, new LED lights require substantial changes to the columns and to the luminaires. But even with these complexities it seems to always make financial sense for authorities to move to LEDs.

Chart 19

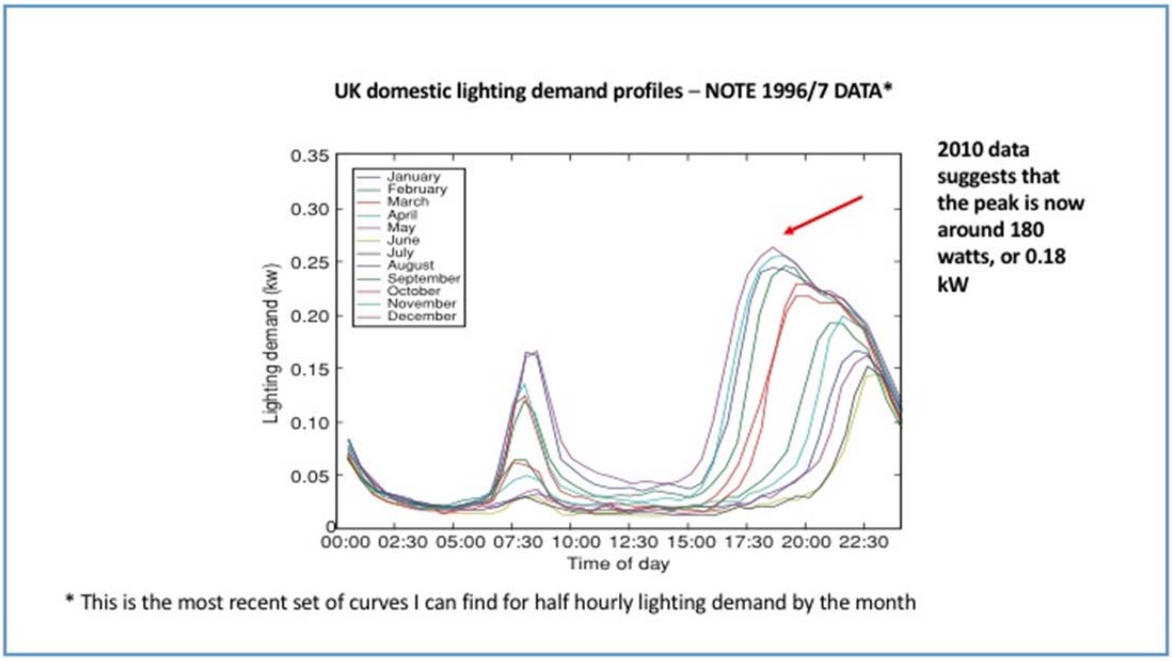


Domestic lighting

- We have more reliable data on domestic lighting use. Unsurprisingly, surveys show sharp rises in electricity consumption as the light fades on winter afternoons.

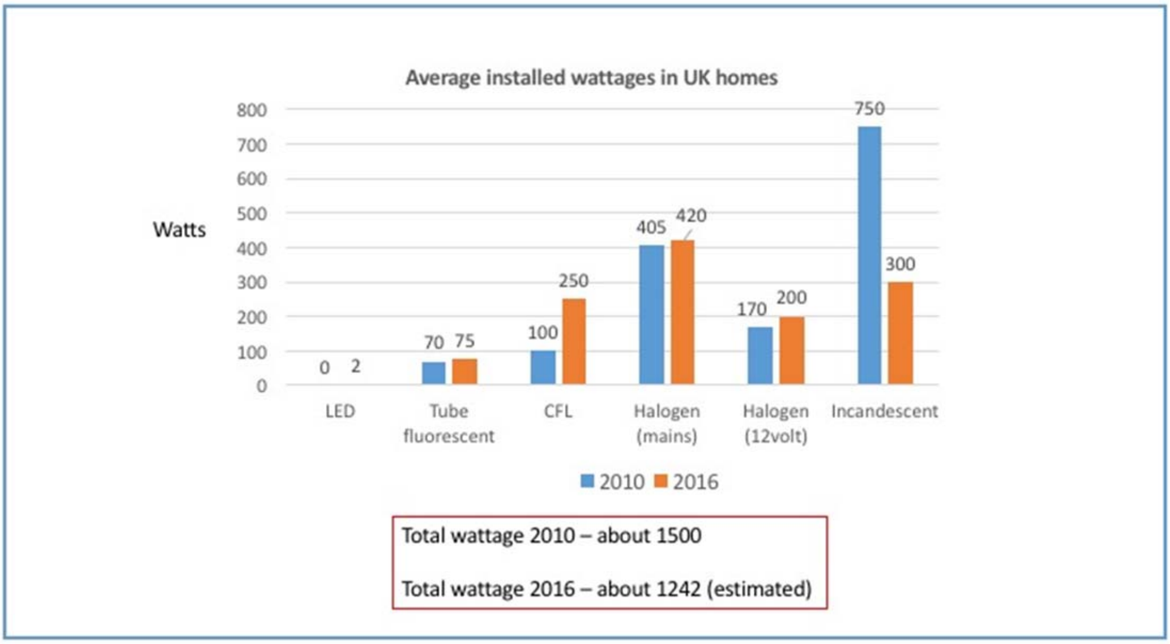
- The chart below shows the pattern of average lighting consumption for each month. The data comes from nearly 20 years ago but the steep rise in the winter months will persist today.
- Then, peak December demand was estimated at around 270 watts for the average home. The switch from conventional incandescent bulbs to CFLs will have pushed the maximum down. However, this reduction has been partly counterbalanced by a rise in the number of lamps in the average home as well as a rise in the percentage that are now halogen. (Halogen bulbs are only slightly more efficient than conventional incandescent bulbs).
- Most estimates suggest the maximum December usage figure is now around 180 watts per home at peak time.

Chart 20



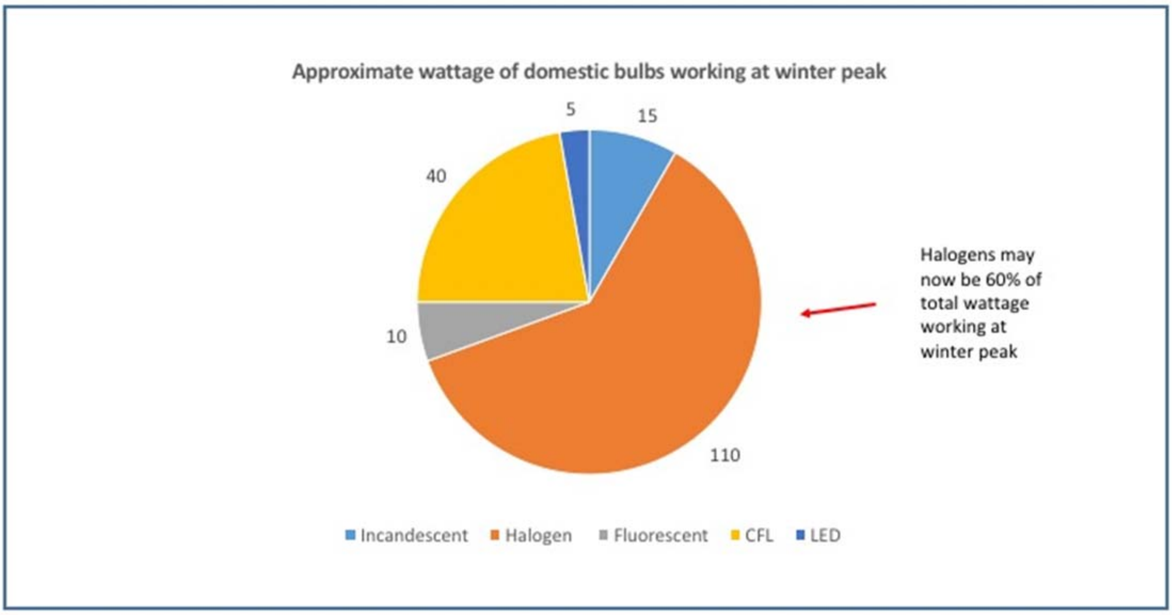
- The total number of bulbs in the average UK home is about 35, with a wattage of around 1240. (This figure is my estimate since the last large scale survey was in 2010, before much of the domestic switch to CFLs).

Chart 21



- The composition of total wattage installed is only a poor guide to the use of lighting at the point of peak demand. The lights in use at 5.30 pm are more likely to be halogen bulbs because these are in areas that are being used then. As a result, halogen bulbs are a more important driver of peak demand that the average 24 hour figure.
- The chart below estimates the composition of peak domestic lighting demand, split by type of bulb. I think that the total usage of LEDs is about 110 watts out of 180 watts, or about 60%.

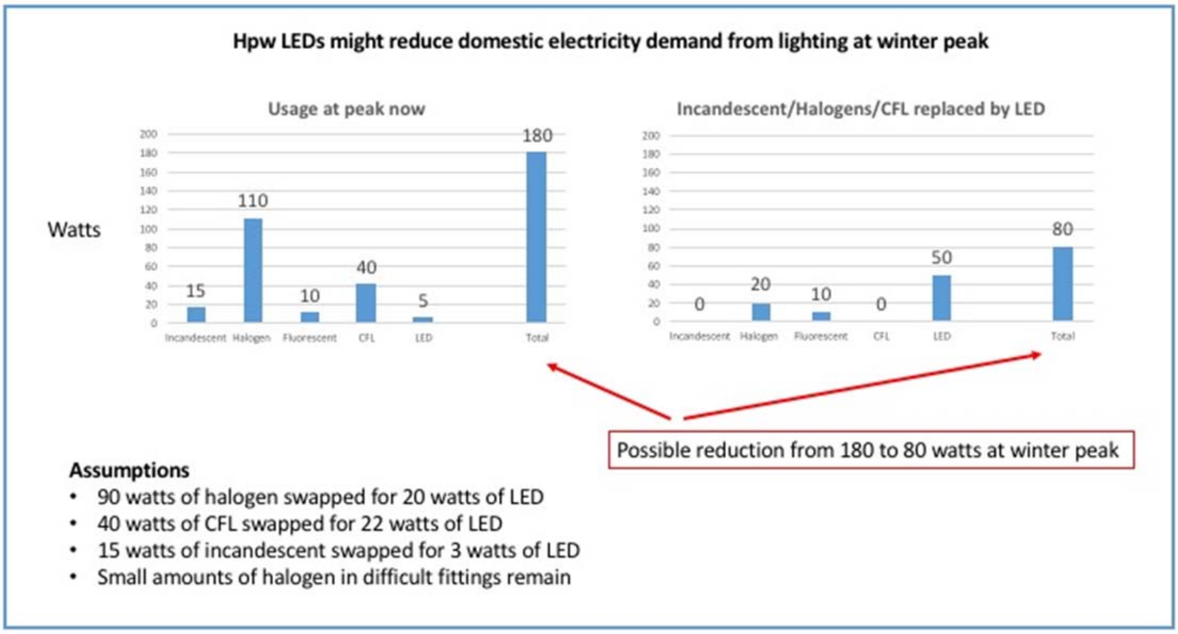
Chart 22



- Not all of the non-LED bulbs can be immediately replaced by LEDs. LEDs can have different shapes and may need better heat evacuation than is provided in current domestic luminaires. In the chart below, I suggest that today's maximum demand of about 180 watts per average household can probably be comfortably cut to about 80 watts.

- The core assumptions that drive this forecast are listed in the chart. LEDs are assumed to be over 4 times the efficiency of the average halogen bulb that they replace.

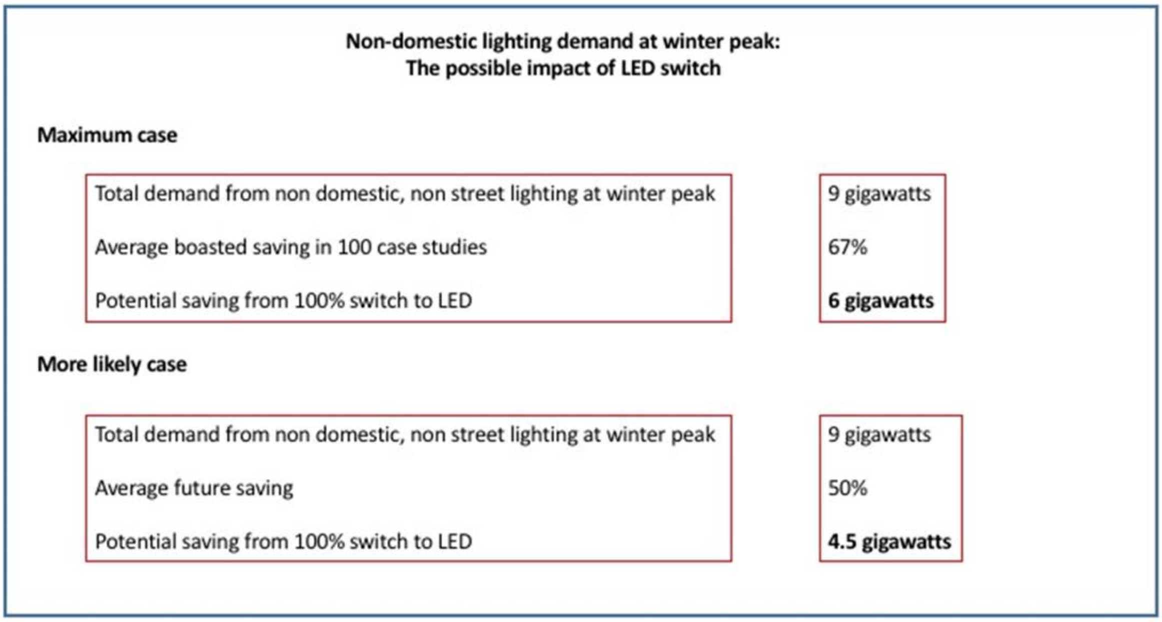
Chart 23



Summary of electricity savings

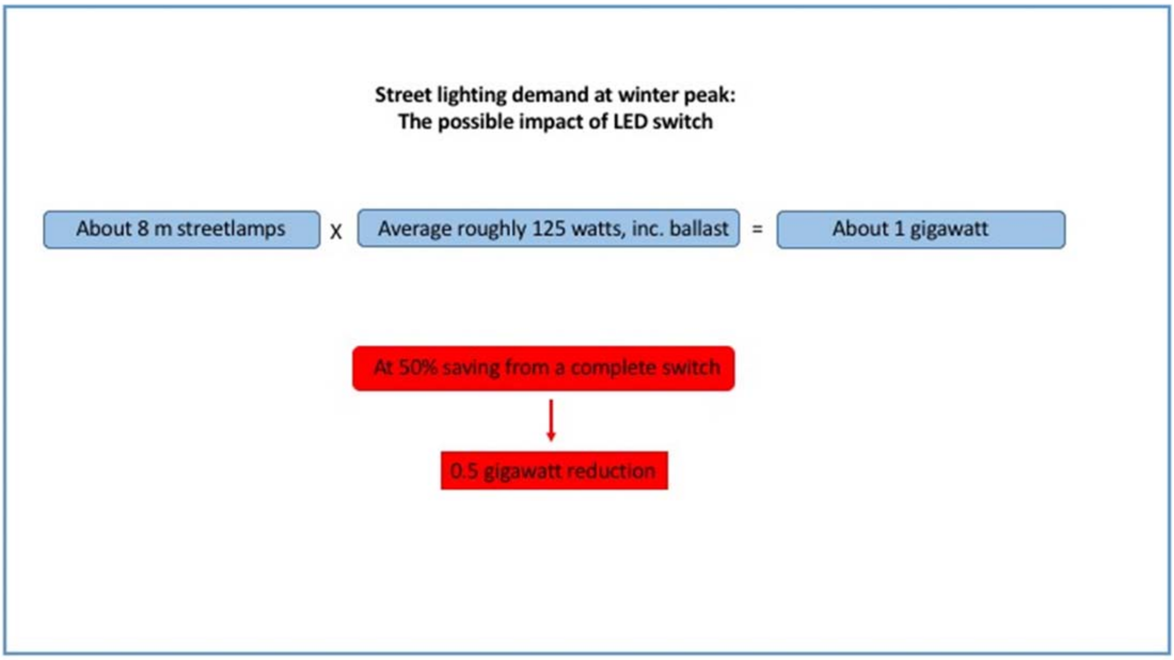
- I have estimated the maximum savings for the three segments: non-domestic, street lighting and domestic. The results are summarised in the charts below.

Chart 24



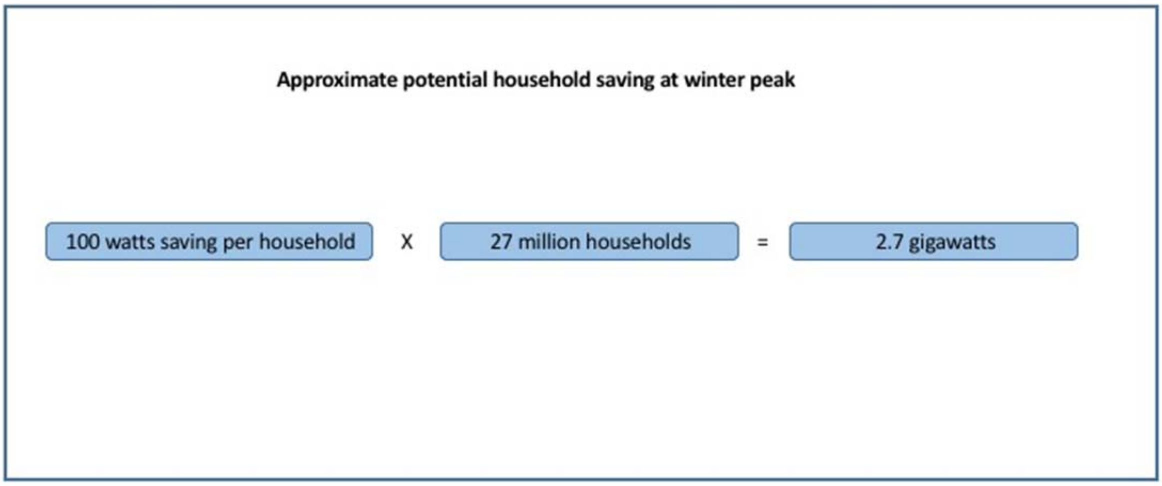
- Chart 24 suggests that a 100% switch in businesses and public sector could realistically be expected to cut peak demand by about 4.5 GW. It could be more.

Chart 25



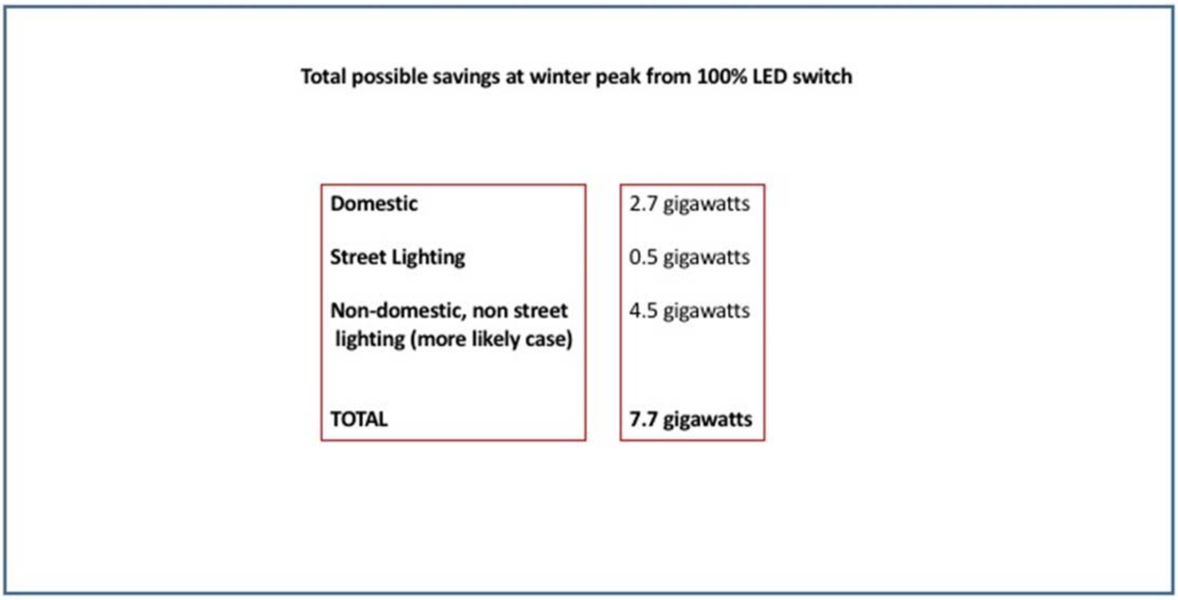
- If street lighting demand is also halved by a switch to 100% LED, the reduction in peak winter demand may be about 0.5 GW.
- A 100 watt saving in 27 million UK households will reduce peak demand by about 2.7 GW as shown in Chart 26.

Chart 26



- In aggregate, the UK might be able to reduce peak winter demand by a total of about 7.7 GW.

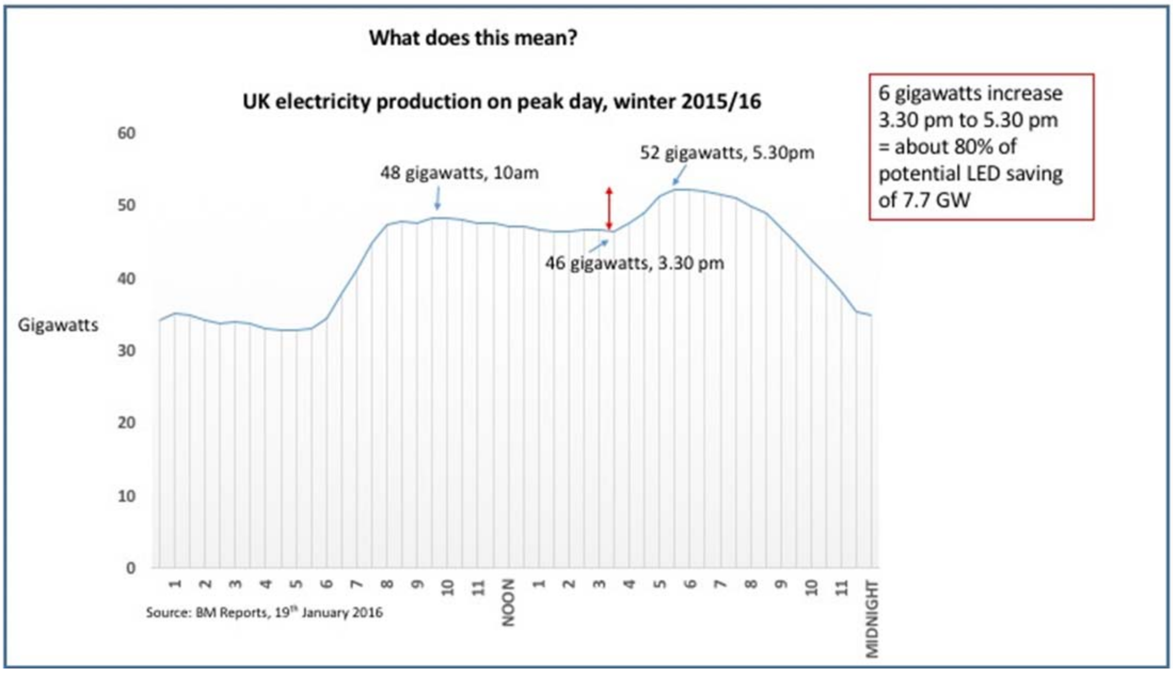
Chart 27


Total possible savings at winter peak from 100% LED switch

Domestic	2.7 gigawatts
Street Lighting	0.5 gigawatts
Non-domestic, non street lighting (more likely case)	4.5 gigawatts
TOTAL	**7.7 gigawatts**

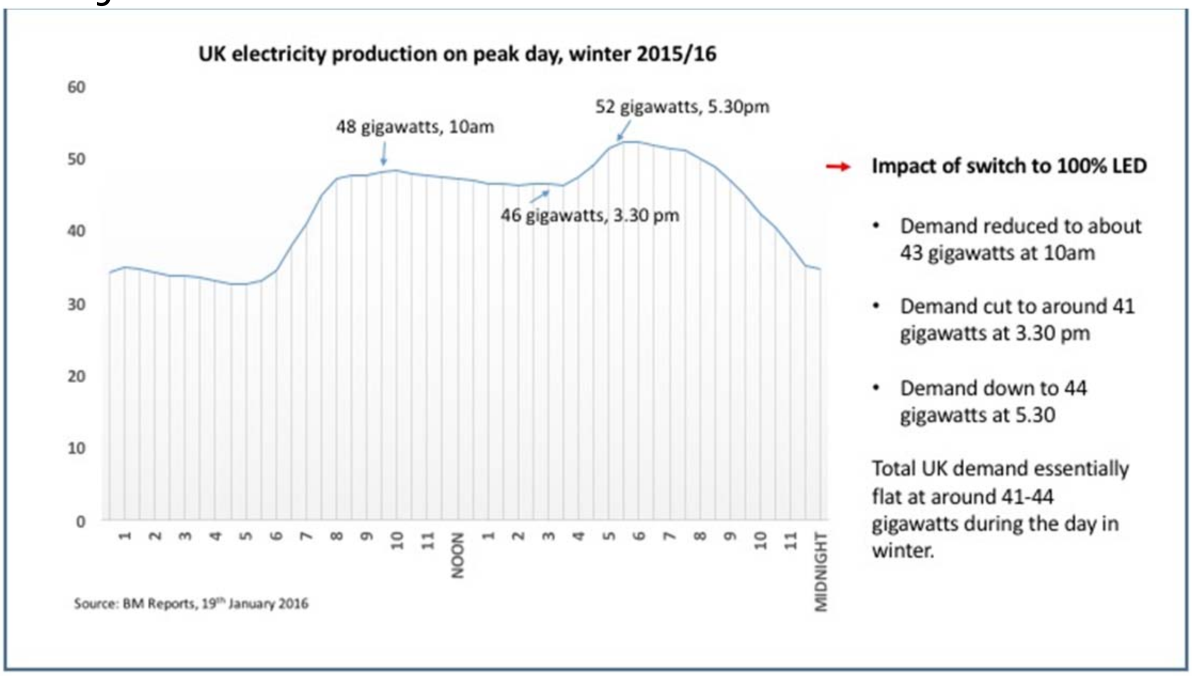
- The impact of this saving would be to wipe out the early evening hump in UK electricity demand

Chart 28



- But it needs to be remembered that electricity demand at 3.30 pm will ALSO be reduced by the LED switch. Power need will be reduced across the entire day, although less in low lighting need periods such as very early morning. Broadly speaking the outcome of a 100% LED world would be to leave UK winter daytime electricity demand flat across the day at between about 41 and about 44 GW. This pattern would provide carbon savings above those expected from merely cutting total yearly power need because fewer power stations would have to engage in inefficient ramping up and down.

Chart 29



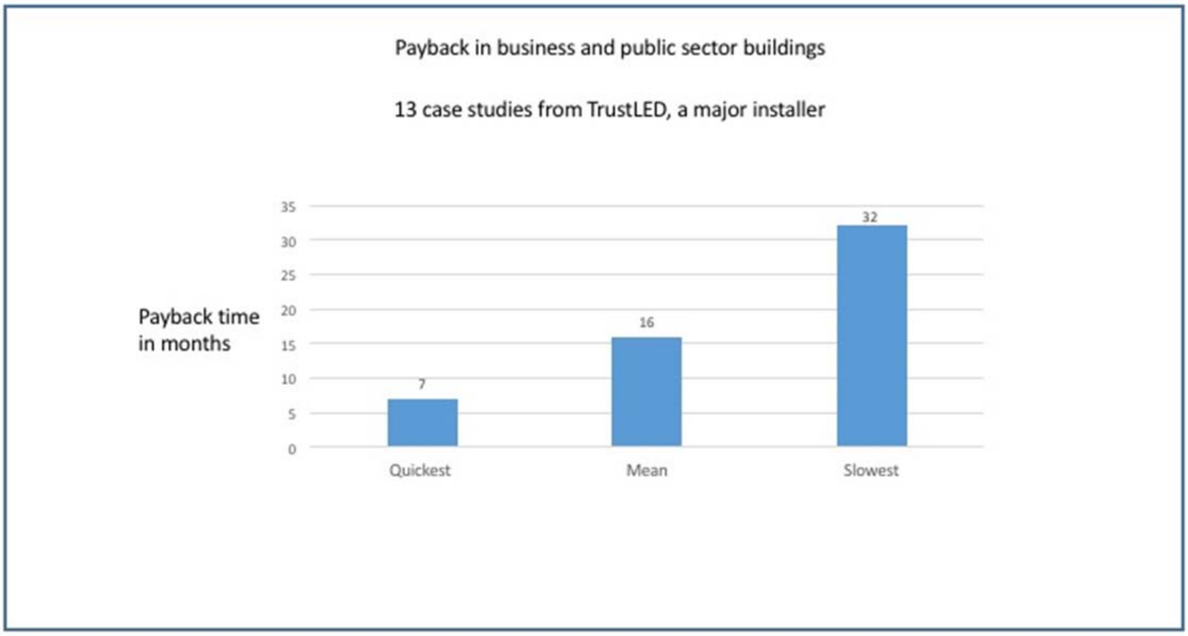
Chapter 3: Cost analysis of LED conversion/switch

Non-domestic lights

Some case studies compiled by manufacturers and installers offer estimates of payback times. As with electricity use reductions, we should be cautious about accepting these numbers without question but they probably have approximate accuracy.

The installer offering the fullest information on payback times is TrustLED. It provides an estimate of the number of months it took the customer to recoup the cost of the installation.

Chart 30



Domestic lights

- The top selling bulbs at Screwfix, a web site and out-of-town retailer owned by Kingfisher, are almost all now LEDs. All the top 10 are. The three most popular are listed below, with their price and a statement of the bulbs they typically replace.
- Charts 32 to 34 estimate the payback periods of these 3 top sellers.

Chart 31

- The savings and payback from replacing house lights depends crucially on a) how many hours a year the bulb is used and b) whether the LED replaces a halogen (or other incandescent) or a fluorescent bulb. Payback is very fast for halogens in high use locations. The chart below gives estimates for a 5 watt LED replacing a 50 watt 240 volt GU 10 halogen.

- LEDs are only approximately 5 times as nominally efficient as halogens, not the 10 times suggested in this comparison. However the amount of light usefully directed downwards is comparable and retailers sell 5 watt halogens as like-for-like replacements for 50 watt halogen downlighters.

Chart 32

Payback time for domestic lamps

5W GU10 LED replaces 50W halogen bulb saving 45W

Hours use per year	Electricity saving/year	Financial saving at 12p/kWh	Payback period
500	22.5 kWh	£2.70	17 months
1000	45 kWh	£5.40	8 months
2000	95 kWh	£10.80	4 months

- A very high use location (such as a kitchen in a home with many family members) might see a lamp being used for something over 1000 hours. Therefore replacing high wattage halogen bulbs in such places will usually have very fast payback indeed. Even a lower use 5 watt bulb will recoup its cost within 2 years.
- Payback is slightly slower for lower wattage LED replacements.

Chart 33

Payback time for domestic lamps

4W GU10 LED replaces 35W halogen bulb saving 31W

Hours use per year	Electricity saving/year	Financial saving at 12p/kWh	Payback period
500	15.5 kWh	£1.86	18 months
1000	31 kWh	£3.72	9 months
2000	62 kWH	£7.44	5 months

- Replacing CFLs with LEDs does not deliver paybacks that are as rapid. The reason is that CFLs are much more efficient than halogens.
- From personal experience, the Screwfix 8.7 watt bulb does, however, deliver more light than a 11 watt CFL.

Chart 34

Payback time for domestic lamps

8.7W Bayonet LED replaces 11W CFL bulb saving 2.3W

Hours use per year	Electricity saving/year	Financial saving at 12p/kWh	Payback period
500	1.15kWh	£0.14	17 years
1000	2.3 kWh	£0.28	8 years
2000	4.6 kWH	£0.55	4 years

The economics of a partial domestic switch to LEDs

- For the typical business or public sector application, and certainly for all street lights, if it makes financial sense to switch to LED, it will do for the entire building, not just a sample of locations.
- For the typical home owner, this is not true. It may make little sense to replace ALL the bulbs in a house. Many do not get enough usage to make the electricity savings worthwhile. A partial switch may be more financially productive for those just interested in saving money.
- High use locations in living areas are the logical focus of switching. So I have estimated what would happen if a householder replaced halogen bulbs in kitchens and other bulbs in the living/dining room. Chart 35 shows the impact of changing 15 LEDs and 6 CFLs in the living areas.
- These 21 bulbs – well over half the stock in the typical home – will reduce the electricity requirement of the house, probably by 250 kWh and possibly as much as 350 kWH, depending on usage patterns. The numbers below assume a 250 kWh saving.
- These figures suggest a payback in 2 years. A house saving 350 kWh would see payback within 18 months.

Chart 35

Switching bulbs to LED in the highest use domestic locations

	Number	Price	Total Cost
CFL replacement	6	£2	£12
5W GU10 replacement	8	£3.80	£30
4W GU10 replacement	7	£2.80	£20
		TOTAL	**£62**
Current average electricity use for lighting			500 kWh
Estimated reduction with LED install			250 kWh
Value of reduction at 12p per kWh			£30
Financial payback			2 years

- I estimated above that peak domestic demand in winter might fall by about 2.7 GW if all bulbs were replaced by LED. If the partial replacement scenario in Chart 35 were carried out in all houses, PEAK demand should fall by a not dissimilar percentage. Conservatively, I have assumed below that National Grid is able to reduce its capacity payments by at least 1.3 GW if the partial domestic switch happened. This adds to the 'social' value of the transition to LED, in addition to the 'private' financial advantage.

Chart 36

Appproximate national economics for partial domestic conversion

Cost of national (partial) conversion (1)	£1,674m
Annual electricity saving (2)	£648m
Annual saving of capacity payment to generators	£65m
'Social payback	Just over 2 years

(1) £62 for 27 million households

(2) 200 kWh a year for 27 million households

(3) £50 a kW per year for 1.3 gigawatts of LED saving

- In domestic housing, and other institutions that extensively use halogens, the savings from switching are also very clear-cut. In addition to electricity reduction, there are often benefits in reducing heat gain.

Where switching pays of the quickest

- The most obvious – and fast payback - circumstances when LEDs make most sense are specified in the chart below.

Chart 39

Type of installation	Reasons for fast payback	Payback time
1. **Halogen in shops, hotel and display environments**	Very significant reduction in electricity use Lowered maintenance costs to replace bulbs and fittings Reduced need for air conditioning to remove heating effects of halogen	Can be less than 1 year
2. **Sodium lamps in rarely occupied 'high bay' warehouse space**	Difficult and costly to replace sodium or other high intensity lamps in 'high bay' warehouses Poor visibility under sodium causes losses because of damage etc Sodium cannot be rapidly turned on and off. So has be kept on all the time. LEDs can be turned on only when needed.	Very quick payback in some locations but usually 1-2 years
3. **Sodium, HID or fluorescent lamps in offices or buildings with substantial natural light in some areas**	Unlike fluorescents, LEDs can be dimmed automatically when areas is receiving good natural light, e.g. close to windows in offices, do not need artificial help. LEDs can be turned on when activated by PIR. Saves electricity and replacement costs	Depends on degree of saving from turning off when not needed

Why isn't the switch happening faster?

- In the case of corporate and public sector users, it is difficult to see a good reason for the slowness of transition.

Chart 38

The lack of any obvious reason why LED transition in commerce and public sector isn't happening fast

- LEDs in business and public sector use already seem to make good financial sense
- And businesses and public sector can benefit from low cost or interest-free loans
- And enhanced capital allowances for profit making companies have additional value
- In the face of these advantages, unclear how direct action by government could improve rate of change
- Social pressure is likely to be more influential

Conclusion

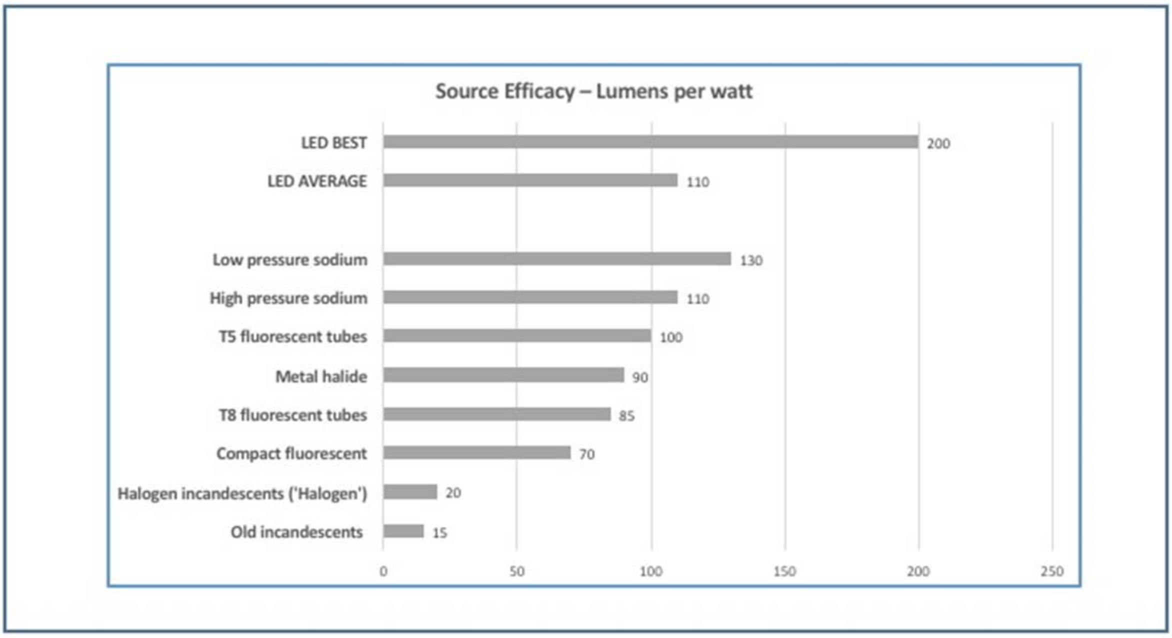
- In many separate ways, LED switching makes obvious sense already across the whole economy and society. The full conversion will therefore eventually happen. Making it happen **quickly** is more difficult. Although domestic lighting is not the most important use of power, I think the earliest focus should be on this segment. LEDs can assist in alleviation of fuel poverty, reduce bills for everyone and may never need replacing. I suggest a number of ways of making the switch happen faster, led by a proposal to carry out conversion in a few typical homes to attract attention and provide the data firepower to convince the press and other intermediaries. This can be followed by other tactics in domestic lighting and in other lighting applications, such as schools. Initial case studies, carried out and publicised by Greenpeace will be powerful allies.
- Lighting is responsible for about 15 gigawatts (29%) of winter peak electricity demand. A complete conversion to LED might save over half of this total, removing the late afternoon/early evening peak. A highly memorable target for Greenpeace would be to reduce the hump of late winter afternoon demand by 3.2 gigawatts, the proposed generating capacity of Hinkley Point C. This is only just over 20% of total lighting demand at peak. So it is a feasible and clearly realistic target – it's just a question of how quickly it can be attained.

Annex 1: Benefits of LEDs

Luminous efficacy of LEDs

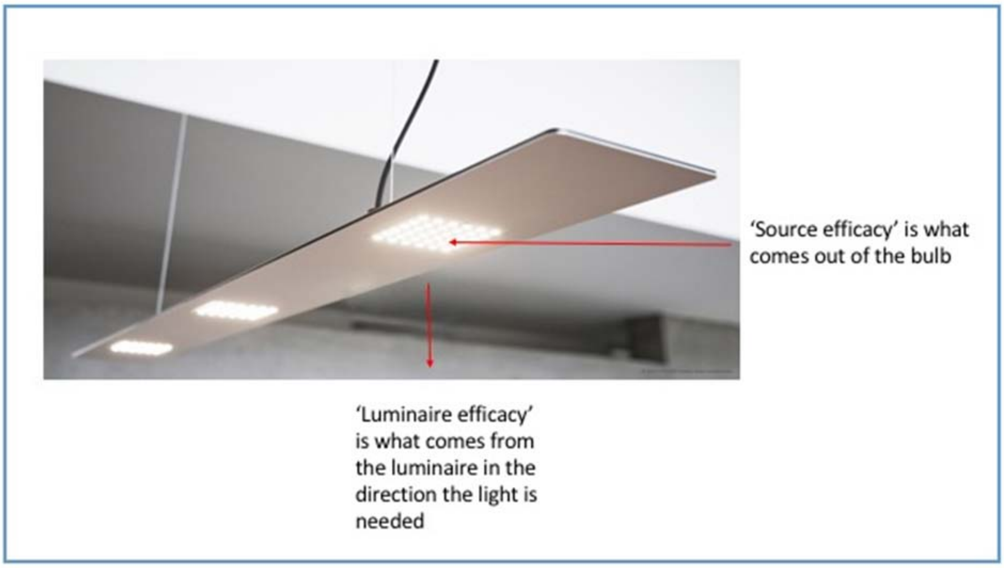
- This is a measure of the conversion of electricity into light. Reasonable quality LEDs convert about 20% of electricity into light today. This compares to a few percent for incandescent bulbs. LEDs will improve further, possibly doubling in efficacy in a few years.
- The measure commonly use for luminous efficacy is 'lumens per watt' or Lm/w. Standard LEDs offer about 100-120 Lm/w.

Chart 1



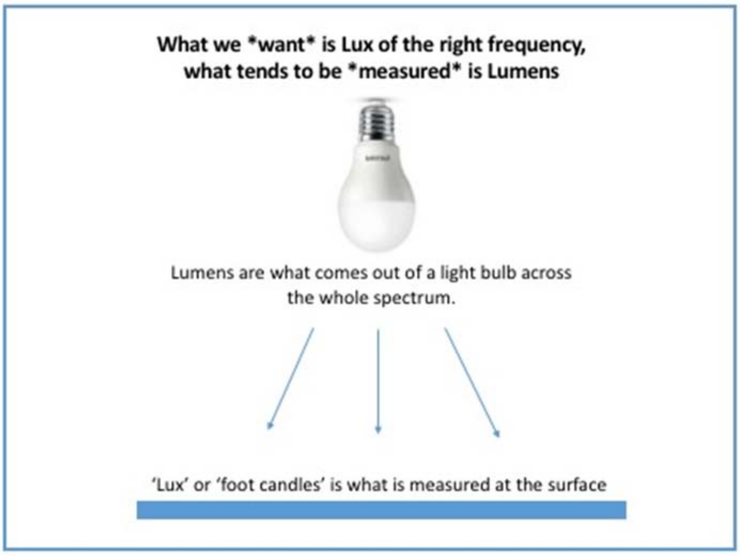
- LEDs are better than Chart 1 suggests. They send all their light in one direction. By contrast, sodium bulbs send light out in all directions. Some of this is reflected inside the luminaire towards the desired direction but some - perhaps up to 40% - is lost. Other highly efficient bulbs, but not LEDs, also require energy to be employed to power the 'ballast' the associated equipment that starts up the bulb.
- When full 'luminaire efficacy' is measured, LEDs score particularly well.

Chart 2



- LED light is also more useful to the human eye than, say, the light from sodium lamps in that it can be tuned towards parts of the light spectrum which we see more effectively (e.g. green).
- So in terms of what we want, rather than what is conventionally measured by 'Lumens per watt', LEDs also perform well.

Chart 3



The less obvious benefits of LEDs

- LEDs have several other marked advantages

Chart 4

Other advantages of LEDs

- They are (usually) dimmable. So the brightness can be adjusted as required, e.g. as sunlight fades.
- The 'colour temperature' can be tuned to, for example, 'daylight'.
- LEDs turn on immediately. Unlike a sodium lamp or a CFL that takes minutes to get to full brightness, an LED responds within milliseconds Importantly, this means that they can be turned off and on as required.
- LEDs last a very long time, perhaps over 50,000 hours of use.
- They offer very good colour rendering. That is, the light gives an accurate colour to an object that is being lit in the eyes of the beholder. This is a particular advantage against sodium
- No ultra-violet light. (Important in e.g. libraries, museums, shops and other places where objects might fade).
- No mercury.

- In specific market segments, these advantages can provide an overwhelming reason to switch to LED.

Chart 5

Market segment	Key LED advantages other than power use
Car Parks	Allows for major but inexpensive improvement in illumination. Some anecdotal evidence that people feel safer in 5000 K light
Factories	Bulb replacements far less frequent, improving safety and possible reduction in process downtime. Natural light may be safer because outline of objects is clearer to the eye.
Hospitals	As Shops, Offices
Hotels	Halogen has to be replaced often, so far fewer bulb changes. Hotel corridors said to be subject to heat gain from 24 hour lighting, so air conditioning benefits.
Offices	Lower maintenance costs, lower heat gain, clearer light, can use PIR, can reduce lumens close to natural light sources. Some evidence of improved productivity if colour temperature is close to sun's light (around 5,000K)
Restaurants	As Shops
Schools	Reduce heat gain in classrooms. Some evidence of possibly improved learning, concentration in natural (5000 K) light
Shops	Often replace halogen, so far fewer bulb replacements. Far lower heat output into shop, reducing A/C needs. Better colour rendering, important for e.g. jewellery, clothes.
Sports Halls	Major improvements to illumination possible. (Most locations struggle to meet lux necessary to hold competitions). In many sports, eg squash, reduction in bulb changing frequency also important, as is new found freedom to turn lights off between matches (because sodium takes a long time to warm up). 5000 K light better for players in some sports, eg tennis.
Street lighting	Can work with dimmers well. So if no cars, light levels automatically reduced. Far lower replacement costs. Less concern over failures at dangerous junctions that need to be replaced immediately
Warehouse	Huge benefit from not having to replace 'High Bay' bulbs. Better illumination than sodium

- Other lighting technologies are close to their maximum performance. LEDs are still some way from technological maturity.
- LEDs may eventually get to about 300 Lumens/watt. They will eventually therefore be used in almost all circumstances. At this point, lighting's share of peak UK electricity demand is likely to be in single figure percentages, not the 29% of today.

- The chart below shows the lumens per watt of input power achieved in the research laboratories of the technical leader, US company Cree. By 2014, Cree was obtaining lab output of over 300 lumens per watt and this figure – or something close – will be achieved in commercial products in the next few years.

Chart 6

However, it's worth acknowledging that LEDs may not be appropriate in some circumstances.

Chart 37

Disadvantages of LEDs

- Some people do not like even the yellower light that is available for domestic bulbs at 2,700 K, saying it is 'too white'.
- Bulbs are not available to fit all luminaires. Small GU10 capsules for kitchen use do not fit in standard fittings. Householder will have to buy new luminaire with integrated lamps. (Lamps are non-replaceable).
- In commercial environments, also sometimes necessary to replace luminaires, substantially raising the cost of transition.
- Although LEDs are very efficient, they need to have adequate heat dissipation. LEDs generate heat at the semiconductor surface, whereas most heat from bulbs is transmitted as infra-red, and thus away from the bulb. This can pose problems in some locations.
- LEDs slowly fade. A good performance is 70% of initial output after 50,000 hours. Problems of poor hear dissipation cause faster degradation.
- Advantage/disadvantage. LEDs are inherently DC.