BNCL04: Commercial Lighting Government Standards Evidence Base 2009: Best Available Technology

Version 1.1

This Briefing Note and referenced information is a public consultation document and will be used to inform Government decisions. The information and analysis forms part of the Evidence Base created by Defra's Market Transformation Programme.

1 Introduction

- The Best Available Technology (BAT) Scenario is a hypothetical projection of what would happen if the best available technologies on the (current and future) market were bought or installed from now on.

- The best available technologies are defined as the most efficient, or lowest energy consuming technologies available on the market, or those which are close to market (where the development stage is completed, but it is not necessary available as a designed product).

- This GSBN covers lamps, ballasts and luminaires used in the commercial sector.

- Commercial lighting covers all internal and external lighting fixed to a building for all commercial (i.e. non domestic) premises including offices, retail units, hotels, public services buildings, industrial units and warehouses.

- The MTP Commercial Lighting models split out lamps by use. While the Non-Domestic Lighting Annexe in 'Product policy analysis and projections 2010' gives data for Commercial lighting at an aggregate level, this GSBN splits out data for each category of use. Lamps are categorised as follows:

  - **'Ambient' lighting**: lighting to give a mood similar to domestic lighting for instance in restaurants, hotels, bars etc.
    Lamps covered: GLS filament, CFL, SSL (solid state lighting - LED or OLED) alternatives for this type of lighting.

- **'Office' lighting**: Linear fluorescent lighting for general illumination of offices and similar spaces.
  Lamps covered: T12, T5, T8 Hal_B2, T8 Hal_B1, T8 Tri_A, T8 Tri_B1, SSL alternatives for this type of lighting.

  The four categories of T8 equate to various levels of efficiency of lamp (Halophosphate vs Tri-phosphor) and ballast (electronic A, or magnetic B1 or B2); it has been assumed that there are no halophosphate lamps with electronic A class ballasts and no tri-phosphor lamps with magnetic B2 ballasts. All T12 lamps are assumed to be Hal_B2 until changed by the EuP measure on Tertiary Lighting; all T5 are assumed to be Tri_A.

- **'Industrial' lighting**: High intensity discharge (HID) lighting for industrial, warehousing, retail shed and large scale leisure use.
  Lamps covered: High-pressure sodium, low pressure sodium, high-pressure mercury, metal halide (excluding compact types), SSL alternatives for this type of lighting.

- **'Display' lighting**: Lamps for accent and display in retail, museums, galleries, offices.
  Lamps covered: Tungsten halogen, compact metal halide, SSL alternatives for this type of lighting.

The category titles are illustrative only and it is not implied, for example, that all fluorescent lighting is used in offices or that all high-intensity discharge lighting is used in industrial settings.

2 Scenario assumptions

Ambient lighting (GLS)

- Sales are set to zero from 2009
- Thereafter lamps are replaced by CFLs and solid state lighting (SSL – i.e. LEDs). The stock of ambient lighting is made up of the following:
  - 2009: 100% CFLs
  - 2015: 28 % CFL, 72 % SSL
  - 2020: 5 % CFL; 95 % SSL
  - 2025 onwards: 100% SSL

Industrial Lighting

1. High-pressure mercury lamps
   - It is assumed that all high-pressure mercury lamps are phased out and replaced with metal halide lamps
2. High-pressure sodium lamps

  - It is assumed that all these lamps switch to a more efficient model of HPS (approx 12% more efficient)
3. Low-pressure sodium lamps
   - It is assumed that all these lamps switch to a more efficient model of LPS (approx 27% more efficient)
4. Metal halide lamps
   - It is assumed that all these lamps switch to a more efficient model of ceramic metal halide (approx 12% more efficient)

Sodium and metal halide lamps are very efficient, so no assumptions have been made about replacing them with LEDs at this time.

Under the BAT scenario, stock of industrial lighting is made up of the following:

- 2009: 9 % HP Mercury; 55.5 % HPS; 3.5 % LPS; 32 % Metal halide
- 2015 onwards: 55.5 % HPS; 3.5 % LPS; 41 % Metal halide

Office Lighting (fluorescent)

1. Halophosphate lamps are removed from the market in 2009
2. T12 lamps are removed from the market in 2009
3. Magnetic ballasts (class B) are removed from the market in 2009
4. Lamps move towards T5 and T8 triphosphors; T5s and T8s are phased out as SSL improves

Under the BAT scenario, stock of office lighting is therefore made up of the following:

- 2009: 30.5 % T5; 26.5 % T8 halophosphate; 40 % T8 triphosphor; 3% T12
- 2015: 44.5 % T5;; 44.5% T8 triphosphor; 11 % SSL
- 2020: 15.5 % T5; 15 % T8 triphosphor; 69.5% SSL
- 2025: 2 % T5; 1 % T8 triphosphor; 97% SSL
- 2030: 100% SSL

Display Lighting

1. Tungsten halogens are replaced with LED units
2. Compact metal halide lamps replaced with LED units

Under the BAT scenario, stock of display lighting is therefore made up of the following:

- 2009: 76 % Compact MH; 24 % SSL
- 2015: 4 % compact MH; 96 % SSL
- 2020 onwards: 100% SSL

3 Scenario outputs

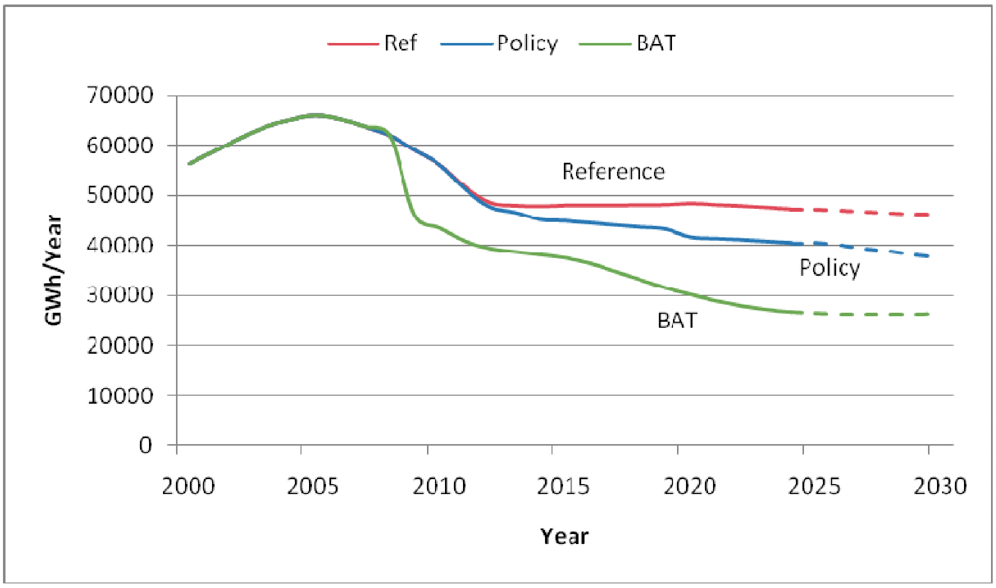

Figure 1: Commercial Lighting energy consumption, 3 scenarios

Table 1 Summary energy[1] and CO_2[2] data,

Energy Consumption (GWh)	**2009**	**2020**	**2030**
Ambient lighting	3,570	1,130	1,020
Office lighting	35,500	23,950	20,110
Industrial lighting	4,920	4,500	4,720
Display lighting	1,940	1,040	1,090
Total	**45,910**	**30,610**	**26,940**

[1] Energy consumption figures for the non-domestic sector in 'Product policy analysis and projections 2010' were scaled down to match DECC projections for overall energy demand (www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx).

MTP data represents the best currently available information based on a bottom-up modelling approach. MTP's data is the basis for detailed energy calculations in 'Product policy analysis and projections 2010'. However, DECC projections indicate that overall energy demand in the non-domestic sector is lower than projected by MTP's detailed models. MTP has assumed that the differences between the DECC overall projections and its detailed bottom-up projections are due to incomplete data on the following inputs for some of its non-domestic products:

- existing product stock;
- existing product efficiency;
- product usage.

The energy consumption figures in these GSBNs have **not** been scaled down, in order to enable constructive stakeholder comment on the MTP input data, and therefore differ from the ones presented in 'Product policy analysis and projections 2010'.

[2] For CO_2 factors, please see MTP Briefing Note BNXS01 Carbon Dioxide Emission Factors for UK Energy Use

Energy Consumption (GWh)	**2009**	**2020**	**2030**
Energy Savings (GWh)			
Ambient lighting	4,550	2,190	2,460
Office lighting	1,600	8,430	9,740
Industrial lighting	160	10	0
Display lighting	6,820	7,150	7,160
Total	**13,110**	**17,780**	**19,350**
CO_2 Emissions ($MtCO_2$)			
Ambient lighting	1.25	0.40	0.37
Office lighting	12.46	8.56	7.19
Industrial lighting	1.72	1.61	1.69
Display lighting	0.68	0.37	0.39
Total	**16.11**	**10.94**	**9.63**
CO_2 Emissions Savings ($MtCO_2$)			
Ambient lighting	1.60	0.78	0.88
Office lighting	0.56	3.01	3.48
Industrial lighting	0.06	0.00	0.00
Display lighting	2.39	2.56	2.56
Total	**4.60**	**6.35**	**6.92**

4 Efficiency

4.1 Summary

- The base efficiency metric used in the Government standards is lamp luminous efficacy measured in lumens per watt. This is a measure of the amount of light emitted by the lamp (in lumens) for the amount of electrical power consumed (rated wattage in watts). The sales-weighted average efficacy of the total new lamp sales is presented.

- For simplicity the efficiency of the ballast (lamp control gear) is not accounted for in this metric although it has been fully accounted for in the model as a whole.

- The efficiency metrics quoted below correspond to values that are relevant to the average wattage of each lamp type. Lamp efficiency is dependent on wattage so efficiency of lamps of lower wattage than the mean wattage will be lower than the figures quoted and for lamps of higher wattage efficiency will be higher.

- In Tables 4-7 no sales of some lamp types are expected in some years – these are shaded in the tables below.

Table 4 Ambient Lighting - Efficiency Metrics

	Average lumens/Watt			
	Sales weighted average	CFL	GLS	SSL
2007	18.4	60	11	48
2010	69.8	60	11	101
2020	156.5	60	11	163
2030	163.0	60	11	163

Table 5 Office Lighting - Efficiency Metrics

	Average lumens/watt							
	Sales weighted average	T5	T8_Halophosphate_B2	T8_Halophosphate_B1	T8_Triphosphor_A	T8_Triphosphor_B1	T12	SSL
2007	89.6	104.0	82.7	81.4	95.5	95.1	76.7	48
2010	100.0	104.0	82.7	81.4	95.9	94.8	76.7	101
2020	158.0	104.4	82.7	81.4	96.1	94.7	89.0	163
2030	163.0	103.9	82.7	81.4	94.5	95.0	89.0	163

Table 6 Industrial Lighting - Efficiency Metrics

	Average lumens/watt					
	Sales weighted average	High Pressure Mercury	High Pressure Sodium	Low Pressure Sodium	Metal Halide	SSL
2007	87.2	54.6	100.0	154.8	82.6	48
2010	105.9	54.6	122.5	154.8	93.3	101
2020	106.3	54.6	122.5	154.8	95.4	163
2030	106.2	54.6	122.5	154.8	95.4	163

Table 7 Display Lighting - Efficiency Metrics

	Average lumens/watt			
	Sales weighted average	Tungsten Halogen	Compact Metal Halide	SSL
2007	24.1	17.0	87.0	48
2010	87.8	17.0	86.1	101
2020	163.0	17.0	85.8	163
2030	163.0	17.0	85.8	163

Table 8 Average efficiency metric for Commercial Lighting based on distribution of sales

		% Sales across all Commercial Lighting					
	Average lumens/watt	**≤17 lm/w**	**17 < lm/w ≤35**	**35 < lm/w ≤60**	**60 < lm/w ≤75**	**75 < lm/w ≤100**	**>100 lm/w:**
2009	81.0	0%	0%	42%	0%	34%	24%
2010	94.5	0%	0%	12%	0%	43%	45%
2011	99.9	0%	0%	11%	0%	36%	52%
2012	94.7	0%	0%	23%	0%	39%	38%
2013	98.8	0%	0%	18%	0%	40%	42%
2014	114.3	0%	0%	4%	0%	35%	62%
2015	124.9	0%	0%	5%	0%	27%	69%
2016	134.5	0%	0%	6%	0%	22%	72%
2017	142.6	0%	0%	3%	0%	17%	80%
2018	148.3	0%	0%	2%	0%	12%	85%
2019	153.9	0%	0%	1%	0%	8%	91%
2020	156.8	0%	0%	2%	0%	5%	94%
2021	159.8	0%	0%	0%	0%	4%	96%
2022	160.7	0%	0%	0%	0%	3%	97%
2023	161.1	0%	0%	0%	0%	2%	98%
2024	161.3	0%	0%	0%	0%	2%	98%
2025	161.4	0%	0%	0%	0%	2%	98%
2026	161.5	0%	0%	0%	0%	2%	98%
2027	161.5	0%	0%	0%	0%	2%	98%
2028	161.5	0%	0%	0%	0%	2%	98%
2029	161.5	0%	0%	0%	0%	2%	98%
2030	161.5	0%	0%	0%	0%	2%	98%

Table 9 Average efficiency metric for Ambient Lighting based on distribution of sales[3]

		% Sales across Ambient Commercial Lighting					
	Average lumens/watt	**≤17 lm/w**	**17 < lm/w ≤35**	**35 < lm/w ≤60**	**60 < lm/w ≤75**	**75 < lm/w ≤100**	**>100 lm/w:**
2009	60.0	0%	0%	100%	0%	0%	0%
2010	69.8	0%	0%	76%	0%	0%	24%
2011	91.8	0%	0%	49%	0%	0%	51%
2012	88.7	0%	0%	58%	0%	0%	42%
2013	97.2	0%	0%	49%	0%	0%	51%
2014	127.1	0%	0%	15%	0%	0%	85%
2015	133.0	0%	0%	20%	0%	0%	80%
2016	137.9	0%	0%	24%	0%	0%	76%
2017	148.8	0%	0%	14%	0%	0%	86%
2018	151.9	0%	0%	11%	0%	0%	89%
2019	157.3	0%	0%	6%	0%	0%	94%
2020	156.5	0%	0%	6%	0%	0%	94%
2021 - 2030	163.0	0%	0%	0%	0%	0%	100%

[3] The S-shaped profile assumed for the transformation between CFL and solid-state lamps and the replacement sales of CFLs lead to some variability in the respective sales of the different products from year to year. Hence it is possible for the sales weighted average efficacy for one year (e.g. 2012) to be slightly lower than the preceding year despite the overall trend being to increased efficacy.

Table 10 Average efficiency metric for Office Lighting based on distribution of sales

		% Sales across Office Commercial Lighting					
	Average lumens/watt	**≤17 lm/w**	**17 < lm/w ≤35**	**35 < lm/w ≤60**	**60 < lm/w ≤75**	**75 < lm/w ≤100**	**>100 lm/w:**
2009	100.0	0%	0%	0%	0%	45%	55%
2010	100.0	0%	0%	0%	0%	47%	53%
2011	99.7	0%	0%	0%	0%	53%	47%
2012	98.9	0%	0%	0%	0%	62%	38%
2013	98.9	0%	0%	0%	0%	62%	38%
2014	106.4	0%	0%	0%	0%	51%	49%
2015	118.8	0%	0%	0%	0%	38%	62%
2016	131.3	0%	0%	0%	0%	31%	69%
2017	140.0	0%	0%	0%	0%	22%	78%
2018	147.1	0%	0%	0%	0%	16%	84%
2019	153.3	0%	0%	0%	0%	9%	91%
2020	158.0	0%	0%	0%	0%	5%	95%
2021	160.4	0%	0%	0%	0%	3%	97%
2022	161.8	0%	0%	0%	0%	1%	99%
2023	162.4	0%	0%	0%	0%	1%	99%
2024	162.8	0%	0%	0%	0%	0%	100%
2025	162.9	0%	0%	0%	0%	0%	100%
2026 - 2030	163.0	0%	0%	0%	0%	0%	100%

Table 11 Average efficiency metric for Industrial Lighting based on distribution of sales

		% Sales across Industrial Commercial Lighting					
	Average lumens/watt	**≤17 lm/w**	**17 < lm/w ≤35**	**35 < lm/w ≤60**	**60 < lm/w ≤75**	**75 < lm/w ≤100**	**>100 lm/w:**
2009	105.7	0%	0%	0%	0%	62%	38%
2010	105.9	0%	0%	0%	0%	61%	39%
2011	106.4	0%	0%	0%	0%	63%	37%
2012	106.1	0%	0%	0%	0%	64%	36%
2013	106.1	0%	0%	0%	0%	64%	36%
2014	106.1	0%	0%	0%	0%	65%	35%
2015	106.2	0%	0%	0%	0%	64%	36%
2016	106.0	0%	0%	0%	0%	65%	35%
2017	106.0	0%	0%	0%	0%	65%	35%
2018	106.1	0%	0%	0%	0%	65%	35%
2019	106.1	0%	0%	0%	0%	64%	36%
2020	106.3	0%	0%	0%	0%	64%	36%
2021	106.1	0%	0%	0%	0%	65%	35%
2022	106.0	0%	0%	0%	0%	65%	35%
2023	106.0	0%	0%	0%	0%	65%	35%
2024	106.0	0%	0%	0%	0%	65%	35%
2025	106.2	0%	0%	0%	0%	64%	36%
2026	106.0	0%	0%	0%	0%	65%	35%
2027	106.0	0%	0%	0%	0%	65%	35%
2028	106.0	0%	0%	0%	0%	65%	35%
2029	106.1	0%	0%	0%	0%	65%	35%
2030	106.2	0%	0%	0%	0%	64%	36%

Table 12 Average efficiency metric for Display Lighting based on distribution of sales[4]

		% Sales across Display Commercial Lighting					
	Average lumens/watt	**≤17 lm/w**	**17 < lm/w ≤35**	**35 < lm/w ≤60**	**60 < lm/w ≤75**	**75 < lm/w ≤100**	**>100 lm/w:**
2009	84.8	0%	0%	0%	0%	100%	0%
2010	87.8	0%	0%	0%	0%	89%	11%
2011	112.7	0%	0%	0%	0%	26%	74%
2012	94.8	0%	0%	0%	0%	79%	21%
2013	103.1	0%	0%	0%	0%	64%	36%
2014	131.5	0%	0%	0%	0%	14%	86%
2015	151.0	0%	0%	0%	0%	0%	100%
2016 - 2030	163.0	0%	0%	0%	0%	0%	100%

[4] In the BAT scenario it is assumed that there will be a rapid increase in sales of ceramic metal halide lamps (in the 70<lm/W≤100 category) in 2009 and a significant increase of sales of solid-state lighting (in the >100W category) in 2011. In 2012, many of the compact metal halide lamps 'bought' in 2009 are being replaced and hence these replacements make up a majority of that year's sales hence the apparent drop in sales weighted efficiency for that year.

4.2 Data sources – efficiency

Table 13 Efficiency data sources

Year	Lamp Type	Reference	Reference date	Author	Justification	Confidence in sources (High/Low)
2009-2030	All	Various manufacturers catalogues	Various years	Various. e.g. Philips, SLI-Sylvania (Thorn), GE, Osram	Lumen and rated wattage values are published for each lamp type. These are used to produce efficiency data from stock and average wattage data.	High confidence in efficiency data. Less confidence in exact product mix year on year.
2009- 2030	All except SSL	UK Electricity and Light Data	1999	BRE Non-domestic energy efficiency model NDEEM	Lamp wattage spread given in survey. Survey results covered significant number of non-domestic installations in UK.	High (except T12, T8 lamps, Compact Metal Halide which is low)

Year	Lamp Type	Reference	Reference date	Author	Justification	Confidence in sources (High/Low)
2009- 2030	SSL	Expert assumption and SSL DOE Roadmap	2009	Navigant Consulting et al for US Department Of Energy	Technical expert opinion based on best available data	Low – projections of the ultimate efficiency of fast-developing technologies so far into the future are necessarily of low confidence

Note: Historic data sources are included in BNCL02: Commercial Lighting Government Standards Evidence Base 2009: Reference Scenario.

4.3 Methodology & key assumptions – efficiency

- Methodology & key assumptions for historic data are included in BNCL02: Commercial Lighting Government Standards Evidence Base 2009: Reference Scenario.

4.3.1 Future analysis

Table 14 Extrapolation & background calculations – efficiency

Year	Methodology & assumptions
2009-2011	All ambient GLS are changed to CFL
2010 - 2030	All solid-state lighting efficiency based on US DOE report projections (see above) and MTP technical expert assumptions.
2009-2030	Industrial high-intensity discharge lamps: all sales of 'standard' versions of lamp types are replaced in 2009 by 'enhanced' versions ('plus' HPS, 'ceramic' Metal halide)
2009-2030	Efficiency of various 'office' fluorescent lamp types does not change with time; efficiency of population increased by transformations from one lamp type to another more efficient one. Least efficient lamp types (halophosphate and B ballast lamps) removed from market from 2009. Transformation towards SSL started in 2013 when SSL becomes significantly more efficient than fluorescent lighting.
2009-2030	Display tungsten halogen lamps removed from market from 2009, replaced initially with compact metal halide.
2009-2030	Compact metal halide lamp sales for display are assumed to move from standard to 'ceramic' forms in 2009.
2010 - 2030	% sales of compact metal halide and SSL shift towards SSL as higher intensity lamps become technically feasible.

4.4 Data issues – efficiency

Table 15 Data issues – efficiency

Issue/risk	Approach taken/rationale
Timing of introduction of appropriate new solid-state lighting technologies is uncertain	Technical expert has made best estimate based on current information
SSL efficacy improvements stated in the USDOE report may be too optimistic	Due to level of uncertainty on the rate of progress it is only possible to follow best available report, which is based on many experts' input within the USA

4.5 Confidence level – efficiency

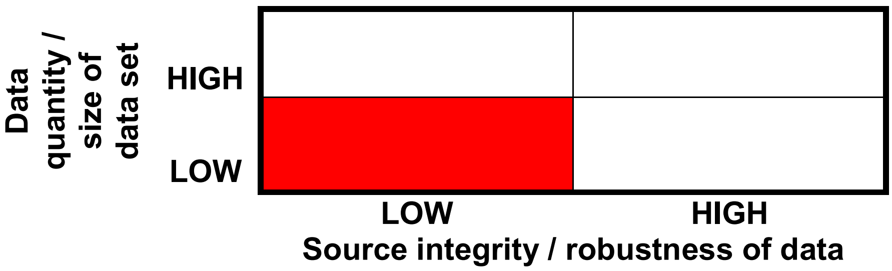

Figure 2 Confidence indicator for efficiency data

- Impacts in the BAT Scenario are based on a stock mix that has not been fully surveyed since 1994.

5 Other issues

- There are recognised health impacts that can result from the use of CFLs for people with pre-existing light-sensitive disorders, estimated as affecting an absolute maximum of 0.05% of the population, and those with some specific visual impairments. These have been taken into account when future sales/stock of each lamp type used was estimated. Alternative light sources (e.g. efficient halogens and UV filtered fluorescent tubes) remain available.

- Solid-state lighting is a new and rapidly developing technology so estimates about when particular lamp replacements will be available and cost-effective are uncertain.

Related MTP information

- BNCL01: Commercial Lighting Government Standards Evidence Base 2009: Key Inputs
- BNCL02: Commercial Lighting Government Standards Evidence Base 2009: Reference Scenario
- BNCL03: Commercial Lighting Government Standards Evidence Base 2009: Policy Scenario
- BNCL KO01: Commercial Lighting Government Standards Evidence Base 2009: Key Outputs

Changes from Version 1.0

- Data tables updated since Commercial Lighting was re-modelled in early 2010, following stakeholder feedback on the 'Saving Energy Through Better Products and Appliances' document. As a result of this feedback, higher usage hours and lower stock data for all sectors have been used as inputs in the models.
- Minor changes to GSBN template

Consultation and further information

Stakeholders are encouraged to review this document and provide suggestions that may improve the quality of information provided, email **info@mtprog.com** quoting the document reference, or call the MTP enquiry line on +44 (0) 845 600 8951.

For further information on related issues visit **http://efficient-products.defra.gov.uk**