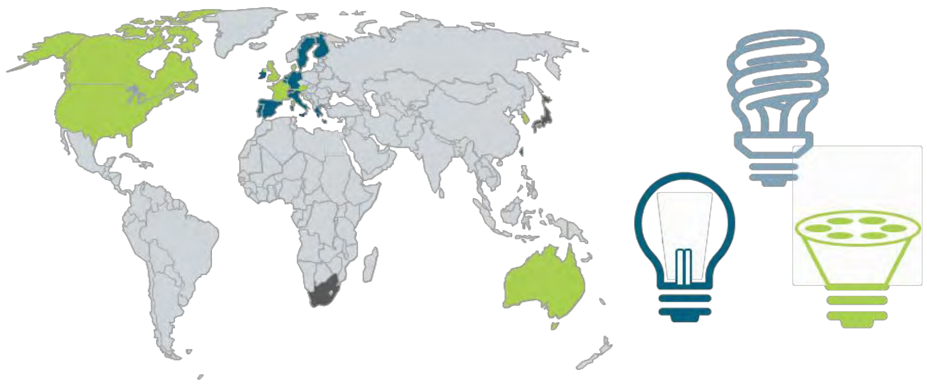
Technology: Lighting: Market Impact of ‘Phase-out’ Regulations



Participating countries:
Australia, Austria, Canada, Denmark, France, Republic of Korea, UK, USA

Other funding countries:
Netherlands, Japan, South Africa, Switzerland, Sweden

Other regions covered:
EU, Taiwan

Draft Benchmarking
Impact of ‘Phase-Out’ Regulations on Lighting Markets

Issue Date: July 2011

For further information refer to http://mappingandbenchmarking.iea-4e.org/matrix
or email operating.agent@mapping.iea-4e.org

Summary for policy makers

Introduction

This benchmarking has been undertaken as part of the IEA's Mapping and Benchmarking Annex of the Efficient End-use Electrical Equipment Implementing Agreement (4E).

In many parts of the world the lighting market is going through a significant period of transition. This transition is a combination of 'regulations to phase-out inefficient lighting' and the market entrance of new products, in particular new types of halogen lamps and LEDs. As a consequence, Mapping and Benchmarking Annex participants have agreed that rather than examine the comparative efficiencies of individual products as is normally the case (for example, a comparison of the efficiencies of compact fluorescent lamps, or CFLs, between markets), the analysis will seek to:

- Compare the approach and stringency of the various 'phase-out' regulations[1] being introduced by each Annex participant and others;
- Compare changes in the *type* of products entering each market which should indicate any major outcomes of the various policy implementations to date;
- Identify changes in the overall *average efficacies* (efficiencies) of the new products entering the market which should indicate longer term efficiency improvements of the installed stock;
- Identify key areas of concern for policy makers, including areas where additional or modified policy intervention may be required in the future.

The products being investigated have been restricted to those lamps applicable to the domestic sector (i.e. general service incandescent lamps, halogen lamps, CFLs and light-emitting diodes, or LEDs) but include the sales of these lamps to other sectors.

Observations and recommendations for policy makers

Regulatory approaches

At the macro level, the regulatory actions to phase out the least efficient lamps from the individual markets are very similar in so far as all:

- Are not technology specific, i.e. they are phrased as quantitative performance limits rather than elimination of certain technologies;
- Have exclusions that allow less efficient lamps to be sold, *normally* based on applications where no alternative efficient light source is currently available;
- Are implemented incrementally over time, normally based on lamp wattage or light output;
- Have mandated additional performance characteristics in addition to efficacy;

[1] Primarily regulations related to non-reflector lamps.

- With the exception of Canada and Taiwan, prohibit the sale or import of lamps, not the manufacture or use[2] of those lamps.

However, more detailed investigation identifies some stark differences in the approaches taken. These differences may be grouped as follows:

- There are major differences in **the overall regulatory approach to performance levels**, with indications that regulations based on a continuous and smooth efficacy curve rather than discrete stepped function are likely to yield higher energy savings and reduce a number of risks to policy implementation.
- There are major differences in **the stringency at which the required performance levels are set, and the associated phasing or speed at which the required actions come into force,** which mean not all potential savings are being captured in all markets.
- There is significant variance in **the range of light outputs and products included in the regulations**, again meaning some markets may not be capturing all the potential savings being achieved elsewhere.
- The variation in **products exempted or requiring lower performance levels** is very significant between markets which increases risks to policy success and potentially leaves consumers with lower performing products.

While there is no evidence to date that such differences are adversely affecting individual markets, analysis indicates that these variations have the potential to lead to significant differences in policy outcomes, with some countries/regions attaining significantly higher efficiency levels (and in many cases performance levels) of installed lamps compared with those installed elsewhere.

Impact of policies to remove inefficient lighting and associated issues for policy makers to consider

There is clear and substantive evidence to suggest that regulatory frameworks to remove less efficient lamps from the market are proving successful in Australia, Korea and the UK, with the average efficacy of lamp sales rising by up to 50% in 3 years, despite the fact that most recent policies are not yet 100% implemented in any of these countries.

At present there is no substantive evidence that such regulatory policies are affecting the market elsewhere. However, this should **not** be interpreted as these policies being failures, but rather as a signal that the markets (or at least consumer buying patterns) are not being affected until the policies are very close to coming into effect.

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[2] Canada prohibits the import and interprovincial trade of lamps rather than their sale. Taiwan differs in that it appears currently to be the application of lower efficacy lamps that is prohibited in certain areas (e.g. some types of commercial building), although indications are that it too will follow one of the other approaches in the near future.

Beyond these broad statements of overall impact, there are a number of observations that policy makers may wish to note when monitoring the impact of policies as they come into effect (or when developing or revising existing policies):

- The performance of the Republic of Korea in managing its lighting market has been remarkable. Korea had an average efficacy of all lamp sales of 45 lm/W in 2009. This efficacy level is twice as high as any other country or region that has so far seen any policy impact, and around three times better than countries such as Canada and the USA where the impending policy enforcement dates have so far caused little impact on lamp sales. It appears this strong performance by Korea is due to the extended period in which Korea has been regulating less efficient lamps (beginning in 2003), and the regular revisions of those requirements. These revisions are currently planned to culminate in a fourth generation of regulation that comes into force in 2014. The 2014 regulations will set the most stringent requirement on smaller lamps of all countries reported. It should further be noted that the 2014 requirement is already set, even though the preceding regulations are phased for introduction over the 2009-2012 period. Hence the indication is that regular and well signposted regulatory revision of the lighting market is highly successful.

- There is a strong consumer backlash against the impending removal of inefficient lighting in Austria (Austria has the highest historical level of incandescent lamps of all reporting countries). This backlash resulted in a *doubling* of incandescent lamp sales in the year prior to regulations taking effect. It is not yet clear whether this is a single year event or an ongoing issue during the phased introduction of regulations. However, what is clear is that the effect is counter to the intention of policy makers and will slow the ultimate impact of the policy, as replacement lamps will enter the installed stock at a later date.

  Such a situation was avoided in the UK (it appears) primarily due to a voluntary agreement with major retailers to remove the most inefficient products from sale prior to mandatory regulation within the EU. This removed the opportunity for consumers to stockpile less efficient products. A similar situation occurred in Australia. In Australia no voluntary agreement existed, but there is anecdotal evidence to suggest the close liaison between government, industry and major retailers, and a relatively rapid implementation schedule, resulted in changes in supply similar to those of the UK voluntary agreement.

  Hence, policy makers should be aware that significant delays between the date of announcement and the date at which regulations come into force may result in a short to medium term market effect completely at odds with the intention of the policy action. Thus a balance needs to be struck between allowing time for the supply side of the market to respond, and the potential adverse consumer reaction delaying the ultimate policy impact well beyond the actual date of policy introduction. It is important to note this balance may be very different from that for other regulated products such as appliances due to the low cost, consumable nature of lighting products[3]. If delay is unavoidable, then policy makers should consider mitigation strategies similar to those employed in the UK and Australia.

- In countries where recent regulation is most advanced (Australia and the UK), there is clear evidence that elements of the market are migrating from traditional incandescent lamps to halogen lamps. The proportion of sales of mains voltage halogen (most likely 'look-a-like') lamps has jumped from 5% to 21% in Australia (2009) and 9% to 14% in the UK (2010). While a degree of switching from incandescent to halogen lamps was anticipated, policy makers may wish to note the degree to which this shift is occurring, given that regulatory impact investigations in some jurisdictions appear to have expected very high levels of switching to CFLs rather than market adoption of halogens.

  There is some *anecdotal* evidence that this switch to halogen rather than CFLs may be a particular issue in the USA. In the USA there are indications that a large number and variety of compliant halogen lamps will enter the market prior to the 2014 regulations coming into effect. As there are already indications that the US market is saturated for those wishing to adopt CFLs voluntarily, consumers may generally switch to halogens as the regulations come into force, hence yielding lower savings than may have initially been anticipated.

  However, policy makers in all countries should be aware of this potential shift in their own markets and may wish to monitor development very closely to ensure anticipated policy outcomes are not being distorted.

- At present, evidence suggests there is little actual penetration of LEDs into the domestic lamp sector. However, the majority of data available is for the period up to and including 2009 and thus may not capture the most recent trends in the market.

There are a number of other issues that could affect the outcomes of 'phase-out policy'. It appears that *technical* compliance and compliance with the *spirit* of the regulations should be relatively easily accomplished in all regions. However, policy makers may wish to ensure that sufficient market monitoring is in place to quickly identify if:

- There is a significant increase in sales of lamps falling outside the lower or upper lumen or wattage limits of the regulations. This would indicate consumers are switching to smaller or larger lamps rather than adopting the more efficient alternatives as intended by the regulations;

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[3] In general, consumers will not "stockpile" appliances for use when their existing products are to be replaced, so policy has the potential to impact as soon as it comes into force. However, for lighting, both the product size and price are very low so consumers are in a position to stockpile significant quantities, hence having the potential to delay significantly the actual impact on electricity consumption.

- There is a significant increase in the sales of lamps that are excluded from regulations, or that are subject to relaxed requirements (e.g. reflector, shatter resistant or modified spectrum lamps). Such an increase in sales is *likely* to indicate suppliers are bringing products to market that are modified in some way thus enabling the sale of existing products that confound the intent of the policy.

Where policy makers are unable to monitor the impact on actual energy consumption through full stock models, they may wish to do so through monitoring of the efficacy of sales. If this is the case, it is important to do so through the *average efficacy of all lamps sold*, not the *average of all lamp efficacies*[4]. It is also necessary to recognise that monitoring only sales has some distinct shortcomings. In particular, monitoring of sales *cannot* be used as an absolute measure of penetration of a particular lamp type into the overall stock/installations (and hence as a true measure of likely long term energy consumption). Therefore the use of sales information should be recognised as giving only an *indication* of the direction, degree and speed of improvement of the efficacy of the installed lamp stock.

There is one final impact of the phase-out regulations of which policy makers should be aware. The **total number of lighting products sold will fall dramatically**. This fall will be greatest in those markets which currently have low penetrations of CFLs (or LEDs) and where these products are adopted rapidly. However, a fall in sales should be noticeable in all markets where regulations cause the substitution of (generally) short lifetime, inefficient lamps with more efficient, longer life alternatives. Such a fall in sales is already being witnessed in Australia and the UK. Without a full model of the installed stock in each country, it is impossible to predict accurately what the ultimate levels of sales will be. But for the UK it is *estimated* that total number of lamp sales in 2014 will be 75% lower than total lamp sales in 2009 if current trends continue.

Potential for, and benefits of, international alignment of regulations

Despite the wide variety of sizes, shapes, colours, caps, etc, lamps are *the* most globally traded energy consuming product. Further, given the vast array of products available on the market, it is the product group with the least technical difficulty in complying with local cultural and technical requirements. Given the global picture of the supply, and the evidence that all current or pending regulatory requirements can be met by suppliers, the alignment of regulatory requirements between jurisdictions should be technically *relatively* simple if the political environment allows. Such an alignment of requirements would:

- Enable the realisation of substantial additional energy savings. Simply the adoption of the most stringent performance requirements and product scopes *that are currently in place or will imminently come into force* in participant countries would result in an increase in the stringency of existing requirements of over 15% in most participating countries (i.e. the adoption of incandescent requirement broadly in line

[4] The average efficacy of all lamps sold = (sum of all lumens sold)/(sum of all wattages sold). Do not use the average of all lamp efficacies = (sum of efficiencies of all lamps sold)/(sum of lamps sold).

with those specified in the EU for 2016, and the voluntary CFL requirements from Canada in 2008[5]);
- Enable better understanding of, and compliance with, requirements by suppliers;
- Enhance the potential for local and cross border enforcement actions;
- Facilitate increased global trade and *potential* reductions in cost to the consumer.

Similar opportunities exist through the alignment of the various ‘scopes and exclusions’, even if such alignment requires each jurisdiction to add additional exemptions to allow for cultural variation elsewhere. In particular, the European Union has set a 2009 minimum requirement for non-clear lamps (i.e. all covered CFLs and ‘frosted’ lamps that do not provide a point source illumination[6]). This requirement is technology neutral, but has the effect of requiring all non-clear lamps to be of an efficacy equivalent to a covered CFL. While such lamps have limited penetration in many markets, policy makers may want to consider aligning with this requirement for non-clear lamps as there are potential savings to be made with no apparent adverse consequences.

Should the actions outlined above yield an average of ***just 1 watt additional saving*** *per lamp,* when the 6,682 million incandescents installed in the EU 27 countries and the USA are replaced, this would conservatively yield additional savings of over 2.4 TWh/year or approximately 1.95 million tonnes/year of avoided CO_2 emissions. However, this saving is actually likely to be *much* higher in these regions and, given the size of these trading blocs, would send a powerful signal to other countries on the levels of ambition possible, and the benefits in reduced energy consumption (and increased trade) from harmonisation.

Due to the difficulty in revising regulations in a number of jurisdictions, such harmonisation of action is unlikely to be possible during the implementation of current regulatory requirements. However, policy makers should remain aware of the opportunities when these requirements are revised in the future. Further, a more immediately opportunity is presented as test methods and regulatory requirements are developed for LEDs. International coordination of action at this early stage of market penetration (such as that started under the 4E SSL Annex and elsewhere) has the potential to yield dramatic benefits for the consumer through wider choice of high-quality products and to yield reductions in emissions in the medium term.

Other policy action beyond regulation

Beyond regulatory policy, there is strong evidence that voluntary labelling programmes and promotion/subsidy support had an impact on the Canadian, Danish and US sales of CFLs. However, with the potential exception of Denmark, it appears the impact of these

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[5] Although Canada’s 2008 requirements for CFLs are currently voluntary, the Canadian Government reports that in 2010 over 90% of CFLs complied with the requirement and thus there is no apparent problem with the ability of the market to comply should a minimum performance level be set at a broadly comparable level.

[6] For precise definition of a non-clear lamp please refer to the EU mapping sheet at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

programmes (as measured by sales of CFLs) appears to peak relatively quickly over a 2-3 year timeframe and then tail off. From available information it is not possible to establish whether this tail off is due to a gradual reduction in the intensity of the policy intervention, or whether the initial boost in sales rapidly meets the potential demand from those willing to make the switch to CFLs, with later sales falling sharply and reflecting replacement of installed CFLs rather than additional switching by other users.

Contents

1 Introductions and cautions

1.1 Introduction

This document presents the results of the benchmarking of domestic lighting. This benchmarking has been undertaken as part of the IEA's Mapping and Benchmarking Annex of the Efficient End-use Electrical Equipment Implementing Agreement (4E). However, lighting is somewhat different from other products being addressed by the Annex because of the large variety of individual product types and subgroups of colour, shape, light output, etc. Further, in many parts of the world the lighting market is going through a significant period of transition. This transition is a combination of 'regulations to phase-out inefficient lighting' and the market entrance of new products, in particular new types of halogen lamps and LEDs. As a consequence, Mapping and Benchmarking Annex participants have agreed that rather than examine the comparative efficiencies of individual products (for example, a comparison of the efficiencies of CFLs between markets), the analysis will seek to:

- Compare the approach and stringency of the various 'phase-out' regulations[7] being introduced by each Annex participant and others;
- Compare changes in the type of products entering each market which should indicate any major outcomes of the various policy implementations to date;
- Identify changes in the overall average efficiencies of the new products entering the market which will indicate longer term efficiency improvements of the installed stock;
- Identify key areas of concern for policy makers, including areas where additional or modified policy intervention may be required in the future.

The products being investigated have been restricted to those applicable to the domestic sector (i.e. general service incandescent lamps, halogen lamps, CFLs and LEDs[8,9]) but include the sales of these products to other sectors[10]. This approach is *broadly* in line with that used elsewhere in the Mapping and Benchmarking Annex for the definition of individual products based on functionality (i.e. 'illumination'). However, in this case the process has been taken one step further to include technologically very different lighting products.

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[7] Primarily regulations related to non-reflector lamps.
[8] For a summary of the descriptions of the various lamp types (and other definitions), please refer to Annex 1).
[9] The initial data request and the majority of resulting country mappings include information on linear and circular fluorescent tubes. However, as significant use of fluorescent tubes in the domestic environment is limited to a very few countries, none of whom were able to participate in the data collection, fluorescent tubes have been excluded from the benchmarking to avoid unnecessary confusion in interpretation of results.
[10] In almost all participant countries it is not possible to distinguish the sale of 'domestic lamps' that are for use in the home environment from those sold for use in industrial and commercial applications. Further, in almost all cases where policy has been applied to limit sales of less efficient lamps and stimulate sales of more efficient alternatives, the policies have been applied irrespective of actual end use sector. Therefore *all* general service incandescent lamps, halogen lamps, CFLs and LEDs have been considered as 'domestic'. See the detailed product definition and data request for lighting at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

In the creation of the individual country mappings[11], the primary information sought was:

- Details of the regulatory framework for the 'phase-out of inefficient lamps' in each country, plus other additional policy interventions likely to have major influence on the lighting market;
- Sales of products by sub-group and wattage buckets[12] over a number of years;
- Cultural issues that may have influenced product selection within individual countries.

From these data, tables of standardised global lamp efficacies and lifetimes[13] were used to develop comparable mappings for each country/region (Austria, Australia, Canada, Denmark, France, Korea,, UK, USA, the European Union and Taiwan). Based on the data available within each country/region, these mappings present:

- A time series breakdown of overall sales of domestic lighting products within the market as a whole and, where sufficient data were available, by individual products types and wattages;
- The resulting changes in the efficacy of new products sold over time;
- The potential instantaneous lighting output and estimated lifetime light output of the lamp sales to provide an indication of likely impact on the installed lamp base over time;
- The regulatory and cultural issues considered relevant to the individual country.

This mapping information is used within this benchmarking report to create observations on how the varying 'phase-out' and other policy interventions appear to be influencing sales and efficiency of lighting in individual markets. This analysis is used make recommendations on potential policy modifications/revisions that policy makers may wish to consider.

1.2 Important cautions for interpreting and using mapping and benchmarking information

Considerable efforts have been made to ensure the integrity of the data supplied and the subsequent data manipulation and analysis. The generic approaches adopted are detailed in the overall Mapping and Benchmarking Framework[14] and in the Lighting Product Definition[15]. However, to ensure readers are fully aware of the reliability of particular sets of data and any associated assumptions or transformations that have been necessary, the Annex has developed a *'Framework for Grading Mapping and Benchmarking Outputs'[16].* Nevertheless, in this unusual case the benchmarking is looking at the *entire* lighting market within a specific country/region rather than an individual product group. Even in a smaller country,

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[11] 'Country mappings' contain the summary of all source material received from individual countries referenced in this benchmarking. To view individual country mappings please refer to http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5
[12] Refer to Annex 2 for information on 'wattage buckets'.
[13] Refer to Annex 2 for information on standardised 'efficacy tables' and 'lamp lifetimes'.
[14] Refer to Annex framework at http://mappingandbenchmarking.iea-4e.org/
[15] Refer to detailed product definition at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5
[16] This Framework is generally used across all M&B outputs (refer to Annex 4).

the lighting market will consist of several million individual purchases per year of items of varying type, colour, shape and light output, yet the typical cost of each product is just 1-5 $/Euro. Therefore, it is impossible to track all purchases in any market and some degree of modelling and/or assumptions has been required for data submitted by all countries/regions (the specific country modelling and assumptions are reported in the individual country mapping sheets[17]). Further, in order to ensure comparability of data, a number of assumptions have been made which are detailed in Annex 2: *'Wattage Buckets, Standard Efficacy Tables, Standard Lifetimes and Normalisation of Lamps on Differing Voltages'*. Hence the *Framework* is not entirely appropriate. Thus, expert opinions have been used to grade the outputs for likely reliability using the *Framework* as a conceptual template only. As normal, these gradings are based on a robust, illustrative and indicative scale. However, given the degree of modelling required in all cases, no individual data set or overall comparative benchmarking is graded higher than indicative. The specific gradings are shown in Figure 1.

Figure 1. Grading of data and benchmarking by country/region.

Country	Policy information	Mapping data	Benchmarked data	Efficacies
Australia	Robust	• All data Indicative except LEDs and double ended halogen which are Illustrative	• All data Indicative except LEDs and double ended halogen which are Illustrative	• Indicative
Austria	Robust	• All data Indicative	• All data Indicative	• Indicative
Canada	Robust	• All data Indicative	• All data Indicative	• Indicative
Denmark	Robust	• Incandescent data Indicative • Data on CFLs and all halogens Illustrative	• Incandescent data Indicative • Data on CFLs and all halogens Illustrative	• Illustrative
France	Robust	• All data Illustrative except CFLs which are Indicative	• All data Illustrative except CFLs which are Indicative	Illustrative
Korea	Robust	• Majority of data Indicative • All halogen data Illustrative	• Majority of data Indicative • All halogen data Illustrative	• Indicative
UK	Robust	• All data Indicative	• All data Indicative	• Indicative
USA	Robust	• Incandescent data Illustrative • CFL data Indicative	• Incandescent data Illustrative • CFL data Indicative	• Illustrative
European Union	Robust	• All data Illustrative	• All data Illustrative	• Illustrative
Taiwan	Robust	Not Applicable	Not Applicable	NA

In addition, readers should be aware of the following issues:

[17] The specific modelling and/or assumptions that apply to an in individual country or region are provided in the country-specific mapping sheets – see http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

- The report presents data on the sales and average efficacies of new lamps sold within a particular year. However, all markets are currently in transition with consumers switching between lamp types for the same application (this switching is caused by a combination of policy actions and the market entrance of new lamp types). These different lamp types not only have differing efficacies, but also substantially different lifetimes. Such variations in lamp lifetimes mean that changes in the proportion of sales:

    - **Will not** lead to a directly proportional change in the installed lighting stock;
    - **Will not** lead to a proportional change in the efficacy of the stock.

  Given the apparent switch in lighting from short lifetime (generally inefficient) lamps to longer lifetime (generally more efficient) lamps, the installed lamp stock will have a higher average lifetime and higher average efficacy than the average of lamps sold. Hence, all reported proportions of sales and efficacies should be *treated as an indication of the direction, degree and speed of improvement of the efficacy of the installed lamp stock, not an absolute measure of this efficacy or penetration of a particular lamp type.*

- The average efficacies (lamp efficiencies) presented for various lamp types and the markets as a whole are based on the equation:

  Average efficacy = (Sum of all lumens sold)/(Sum of all wattages sold).

  As individual lamp efficacies vary, it is important to note that this will generally present a *very* different value than the equation used when analysing the average efficacy of most products, i.e.:

  Average efficiency = (Sum of efficiencies of all products sold)/(Total number of all products sold).

  However, it is believed the first equation provides a more robust presentation of how sales are likely to impact on overall household and national energy consumption as they enter use[18].

- The definitions of lighting products used in this analysis groups together somewhat dissimilar products. In particular, reflector and non-reflector lamps are grouped into the same categories, as are covered and bare CFLs.[19] Similarly, lamps of differing colour temperatures and lifetimes are grouped. Such groupings are not 100% accurate as each variation will affect other lamp variables, in particular lamp efficacy.

[18] This is because in the first equation, lamps with higher wattages (and hence energy consumption) have a greater impact on the overall resulting average efficacy, rather than all lamps having equal weighting irrespective of consumption as is the case in the second equation.
[19] Note that the efficiencies/losses associated with ancillary equipment (e.g. external ballasts and luminaires) are not included in the analysis.

Given the particular assumptions and data manipulations used, the reported average efficacies of product groups are likely to be slightly higher than the actual efficacies of products in the market. However, such variations are of limited magnitude relative to the variations between lamp types (i.e., between CFLs, low voltage halogens, incandescents, etc). Therefore the differences are believed to have little effect on the reliability of the overall outcomes of the benchmarking.

- 100% reliable sales data are not available for any country.[20] Further, the reporting of absolute number of sales by category would make the outcomes of the benchmarking and associated graphics difficult to interpret. For example, a graphic which is scaled to show sales of incandescent lamps in the USA would make the detailed analysis of similar sales in a much smaller country such as Denmark impossible. Therefore, the majority of the benchmarking refers to the sales of each lamp type within a country as a percentage of the overall sales of all lamps within that country rather than absolute values for the sales of individual lamp types.

- Data from some countries/regions are either not available or have been grouped. For example, data from Korea group all types of halogen lamps (single ended and double ended, mains voltage, and low voltage). This leads to a slight reduction in the reliability of the outcomes related to these particular pieces of data, but again this is believed to have little effect on the reliability of the overall outcomes of the benchmarking. The exceptions are:

  - The data supplied by the USA. Due to difficulties in sourcing data on individual product groups, the US data group all types of incandescent lamps (general lighting service, or GLS and all types of Halogen). This degree of grouping has a significant effect on the reliability of the outcomes due to the number and robustness of assumptions that have to be made when dealing with such data. Further, to benchmark other countries against the USA requires data of other countries to be aggregated in a similar way to the USA dataset. This leads to a significant loss of clarity in interpretation of the outputs. Thus, all benchmarking of the USA against other countries is presented in a separate section (Section 3.2.4 Comparisons with the USA) towards the end of the report. The additional assumptions required to create these comparisons are presented in Annex 3.

  - The data on European Union lamp sales are drawn from a number of sources and significant aggregations and assumptions have been made, hence related outcomes should be treated with extreme caution.

[20] All countries have either used a degree of modelling to establish 100% market coverage, or have reported actual sales for a lower market proportion (e.g. Austria's reported data have 55% market coverage). However, within the context of this report and the use of percentage of sales, data are considered representative of the market (for detailed information on the data sets for each country, refer to individual country mappings at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

Definitions of Terminology used in this benchmarking document are provided in Annex 1.

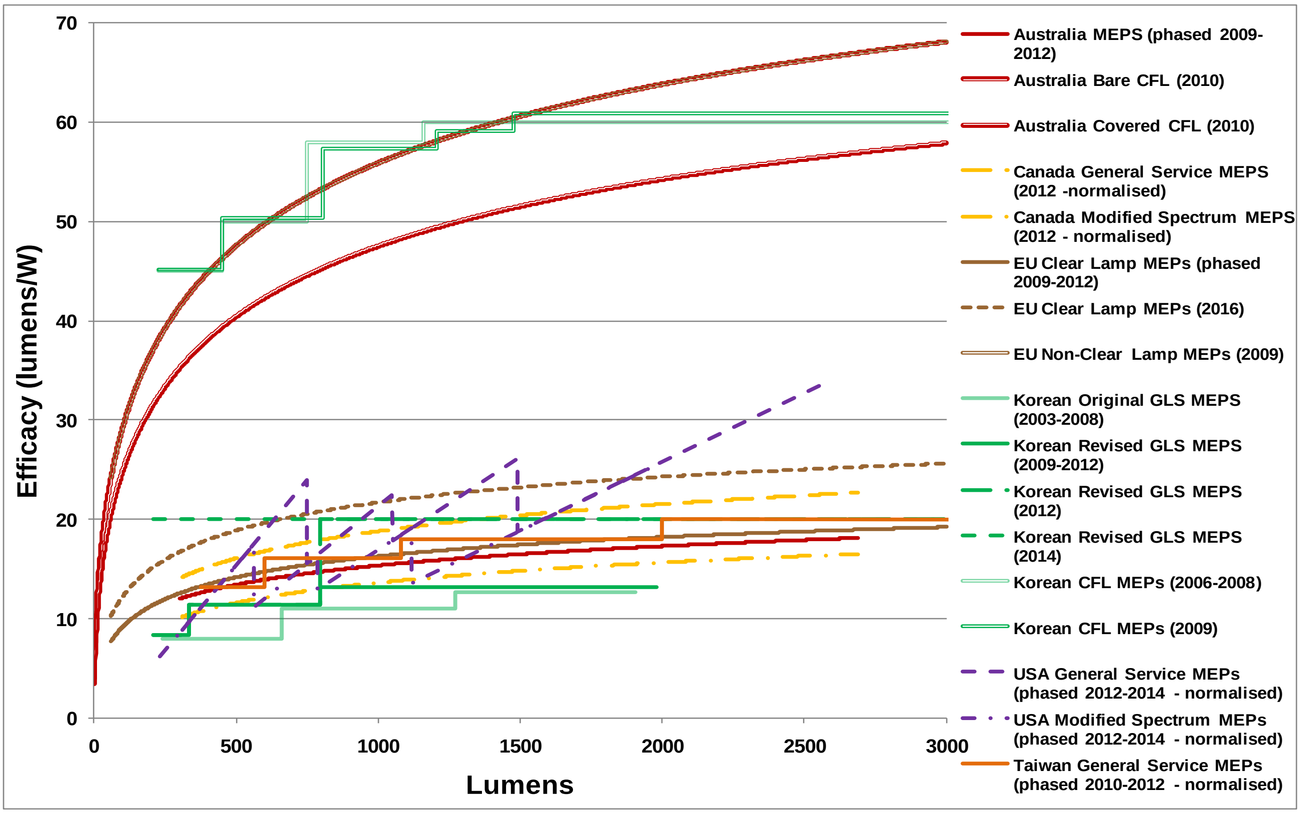
2 Comparison of regulatory approaches and other policy actions

2.1 Observations: regulatory approaches

2.1.1 Regulatory approaches to the 'phase-out' of inefficient lighting

In all countries where data are reported, the primary policy action currently in place or soon to come into force is the mandatory 'phase-out' of the least efficient lighting in the market. Figure 2 gives an overview of the stringency and timings of the various 'phase-out' regulations[21, 22] in the countries reported. Note that the graphic has been normalised for voltage variations.[23]

Figure 2. Normalised overview of the stringency and timings of the various 'phase-out' regulations in the countries reported.



[21] Note that France has a slightly accelerated 'Phase-out' schedule compared with the EU. However, overall the schedule is broadly in line with that of the EU and so is not shown separately.
[22] Note that the USA has an additional requirement that new rules must be in place by 2017 (for implementation no later than 2020) that set a minimum average efficacy of 45 lm/W. Should such a rule not be put in place, a default requirement of 45 lm/W becomes mandatory on *all* non-reflector incandescent lamps. However, this requirement has been excluded from the graphic as the likely requirements of the regulations are not currently clear, and the rule making is not anticipated to begin prior to 2014. Please refer to the USA country mapping at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5
[23] Refer to Annex 2.

At the macro level, the regulatory requirements are very similar between all the countries/regions in that:

- The regulations are not technology specific, i.e. they do not 'ban' a particular lighting technology. In all cases the regulations require lighting products to reach a certain minimum level of efficacy.[24] In a number of countries/regions (Australia and the EU member states), additional minimum efficacy requirements are placed on CFLs;
- The regulations have exclusions that allow less efficient lamps to be sold, *normally* based on applications where no alternative efficient light source is currently available;
- The regulations are implemented incrementally over time, normally based on lamp wattages or light output;
- The regulations have additional mandatory performance characteristics in addition to efficacy. In almost all cases, some minimum lifetime is required for lamps, but in many cases additional requirements are mandated, e.g. lumen maintenance. This is especially true for CFLs with Australia, Korea and the EU member states specifying a range of performance criteria to increase the consumer satisfaction of those switching to CFLs (such requirements also appear increasingly to be being put into place for LEDs and halogen lamps);
- With the exception of Taiwan and Canada, the regulations prohibit the sale of some lamps, not the manufacture or use of those lamps.[25]

However, more detailed investigation identifies some stark differences in the approaches taken. These differences may be grouped into:

- The overall regulatory approach to performance levels;
- The stringency at which the required performance levels are set and the associated phasing or speed at which the required actions come into force;
- The range of light outputs and products included in the regulations;
- The products exempted or requiring lower performance levels.

All these variations are likely to have an influence on the policy outcomes in each market and so are investigated individually below.

2.1.2 Overall regulatory approach to required performance levels

Although worded slightly differently in each jurisdiction, there are three primary regulatory approaches being used:

- Maximum wattage for a given lumen range (USA – see Figure 3);

[24] Although not part of the study, Cuba has implemented a technology based regulatory regime whereby all domestic lighting must be fluorescent tube or CFL. Further, although still under preparation, there are indications that China may regulate inefficient lighting based on technology.
[25] Canada prohibits the import (and interprovincial trade) of lamps rather than their sale. Taiwan differs in that currently it restricts the application of lower efficacy lamps in certain areas (e.g. some types of commercial building) although indications are that it too will follow one of the other approaches in the near future.

- Minimum efficacy requirement for a given power or lumen range (Korea and Taiwan – see Figure 4);
- Continuous curve based on lumen output (Australia, Canada and the EU member states – see Figure 5).

Figure 3. Regulation by maximum wattage for a given lumen range (USA) as declared.

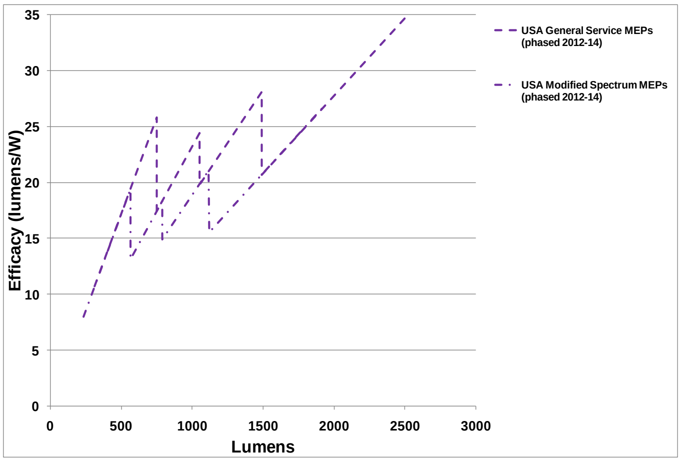


Figure 4. Regulation by minimum efficacy required for a given power/lumen range (Korea, Taiwan).

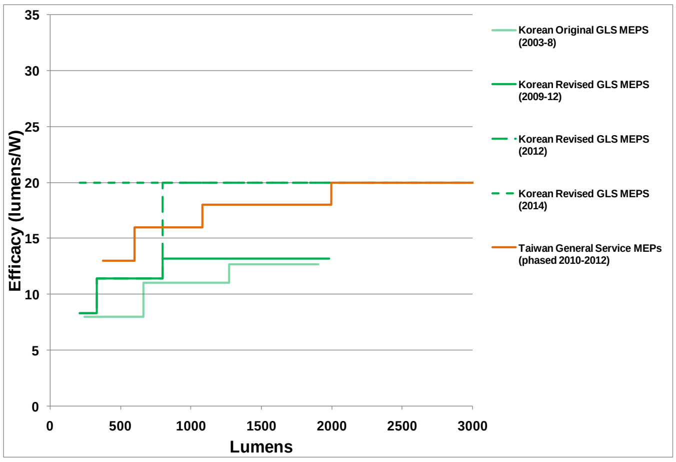
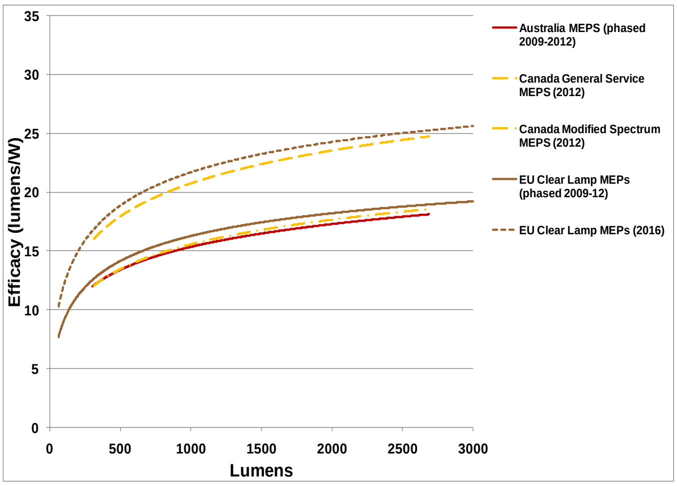


Figure 5. Regulation by continuous curve based on lumen output (Australia, Canada, EU member states).



Each approach has its own merits. In particular, the 'maximum wattage for a given lumen range', and the 'minimum efficacy for a given power range' are very easy to understand. Although paraphrasing the regulations slightly, examples of each are:

- **Maximum wattage for a given lumen range:** For lamps that provide *x-y* rated lumens of light output, the maximum wattage shall be no greater than *z* watts;

- **Minimum efficacy for a given power range:** For lamps between *x-y* watts rated power, the minimum efficacy shall be *z* lumens/watt.

This simplicity makes it relatively easy for manufacturers, retailers, regulators and other market actors to understand and apply. However, as lamps of a particular type tend to become more efficient as their size (light output or wattage) increases, there is the likelihood that not all the potential savings will be captured.

The third approach uses a continuous curve to describe the minimum efficacy requirement for any given light output. This approach increases the likelihood of capturing all potential energy savings but is more complex. As an example, the following equation defines the minimum efficacy requirements for lamps in Australia:

Minimum Efficacy (lm/W) = (2.8 x Ln(lumen)) - 4

This is clearly more complicated for stakeholders to understand, apply and enforce. However, the continuous curve, if set at an appropriate level, captures the maximum energy savings while having the additional benefit of removing two risks to policy implementation. The first risk relates to the potential for increased consumption due to 'bin jumping'. The second risk relates to 'lamp rerating'. Each risk is explained below.

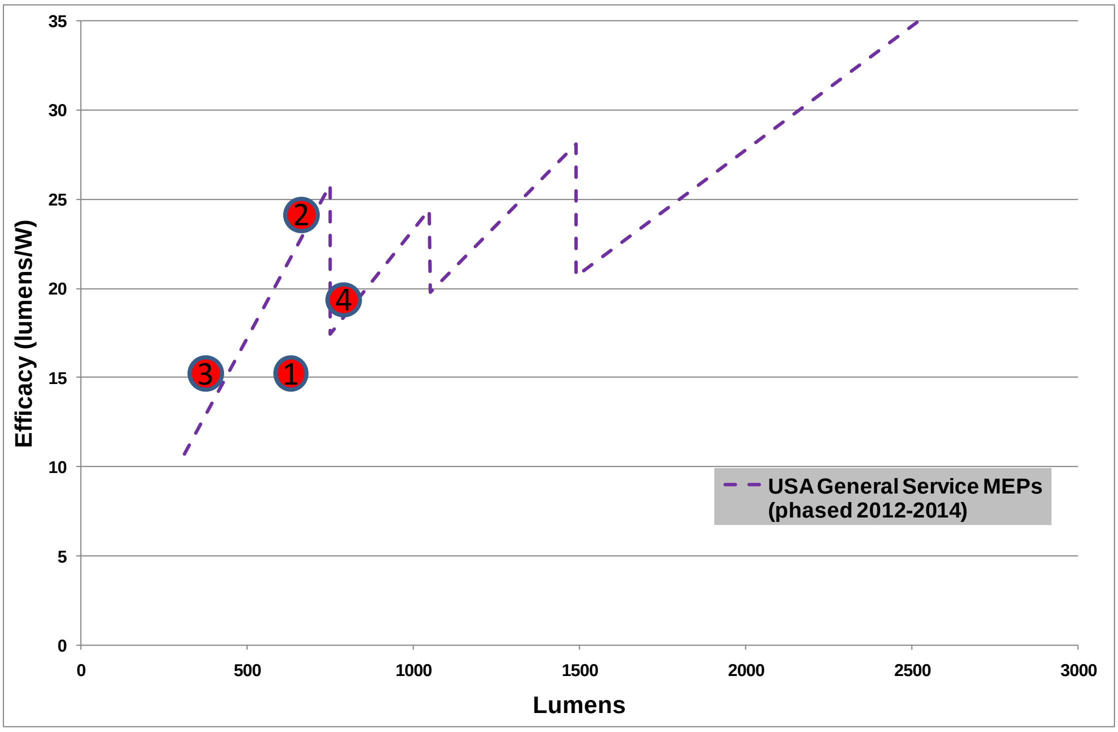
Risk 1: Bin Jumping: Increased Consumption vs Improved Efficacy
The risk of 'bin jumping' is most easily understood graphically. Consider a hypothetical 40 W lamp that is being sold prior to the implementation regulations in the USA. The lamp may have an efficacy of 15 lm/W and thus provide 600 lm of light output (point 1 in Figure 6). As the implementation date of the regulations approaches, suppliers have three options:

a. Remove the product from the market;
b. Provide significant investment to improve the performance of the product (or develop a replacement) such that it maintains 600 lm light output and meets the 24+ lm/W regulatory requirement (point 2 on Figure 6);
c. Provide minimal investment to slightly the re-engineer the product and reduce the lighting output[26] until the lamp complies with the efficacy requirement (point 3 on Figure 6).

There is anecdotal evidence to suggest some suppliers are choosing option c. which is the lowest cost option while still enabling the sale of the lamps. While this produces a compliant lamp, consumers that purchase this lamp as a replacement for the original now receive a significantly lower light output (in this case approximately 400 lm or a 33% reduction in the light output). It is likely a number of these consumers will not be happy with this lower lighting level and hence buy the lamp with the next highest lumen output (for example the lamp at point 4 on Figure 6). This does give a higher light output (approximately 800 lm) and may be a more efficient lamp than the original lamp (in this example 19 lm/W rather than the original 15 lm/W). However, ultimately such action confounds the original intent of the policy intervention as the lamp at point 4 actually *consumes* more energy than the original, in this case 42 W compared with the original 40 W.

[26] Possibly through shortening of the filament length.

Figure 6. Potential 'bin jumping' illustrated by US (maximum wattage) regulations.



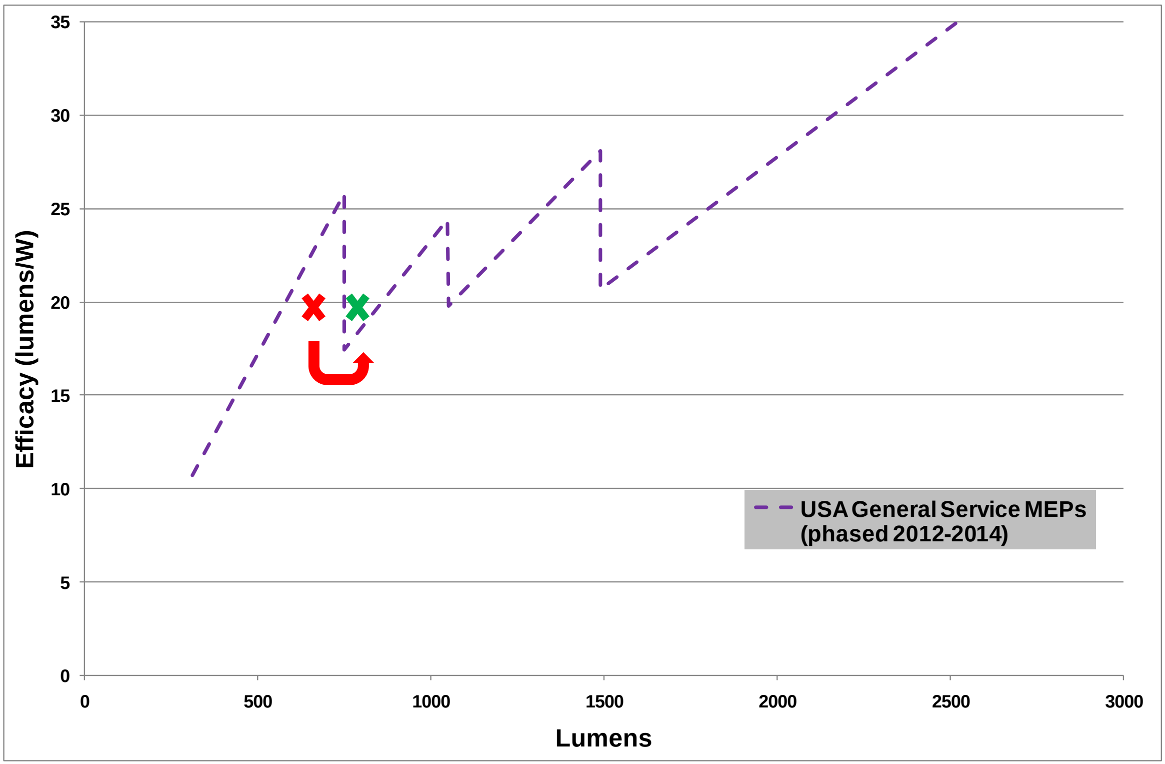
Risk 2: Lamp Rerating

Lamp rerating has a similar outcome to bin jumping and is also most easily understood graphically. Figure 7 again shows the US (maximum wattage) regulations.

Consider a lamp that has a rated lumen output (or equivalent wattage) denoted by the red cross on Figure 7. Such a lamp would not comply with forthcoming US regulations. However, simply by rerating the lamp to a slightly higher lumen output/wattage (illustrated by the arrow), the lamp would comply with the regulations as shown by the green cross. This rerating may be achieved 'artificially' by declaring a slightly higher rating if such an action would fall within the tolerances of the local test method or regulations. Alternatively, the lamp could be rerated by actually increasing the power consumption/lighting output of the lamp through slight re-engineering (typically by extending the length of the filament). In both cases a lamp that would have been deemed to be non-compliant in the USA would suddenly become compliant. If such compliance is achieved through re-engineering, this compliance is again achieved through the perverse outcome of consuming *more* energy[27].

[27] Note that such an outcome is less likely but still possible for regulations defined by a minimum efficacy requirement for a given power or lumen range.

Figure 7. Potential issue with lamp rerating illustrated by US (maximum wattage) regulations.



Hence, although more complicated, policy makers may wish to consider using a continuous curve to define the minimum efficacy requirements. By doing so, savings are likely to be maximised and the risks of bin jumping or lamp rerating are eliminated. At the very least, policy makers should remain aware of the risks of bin jumping and lamp rerating and ensure the desired outcomes of existing regulations are not being eroded by suppliers rerating existing lamps.

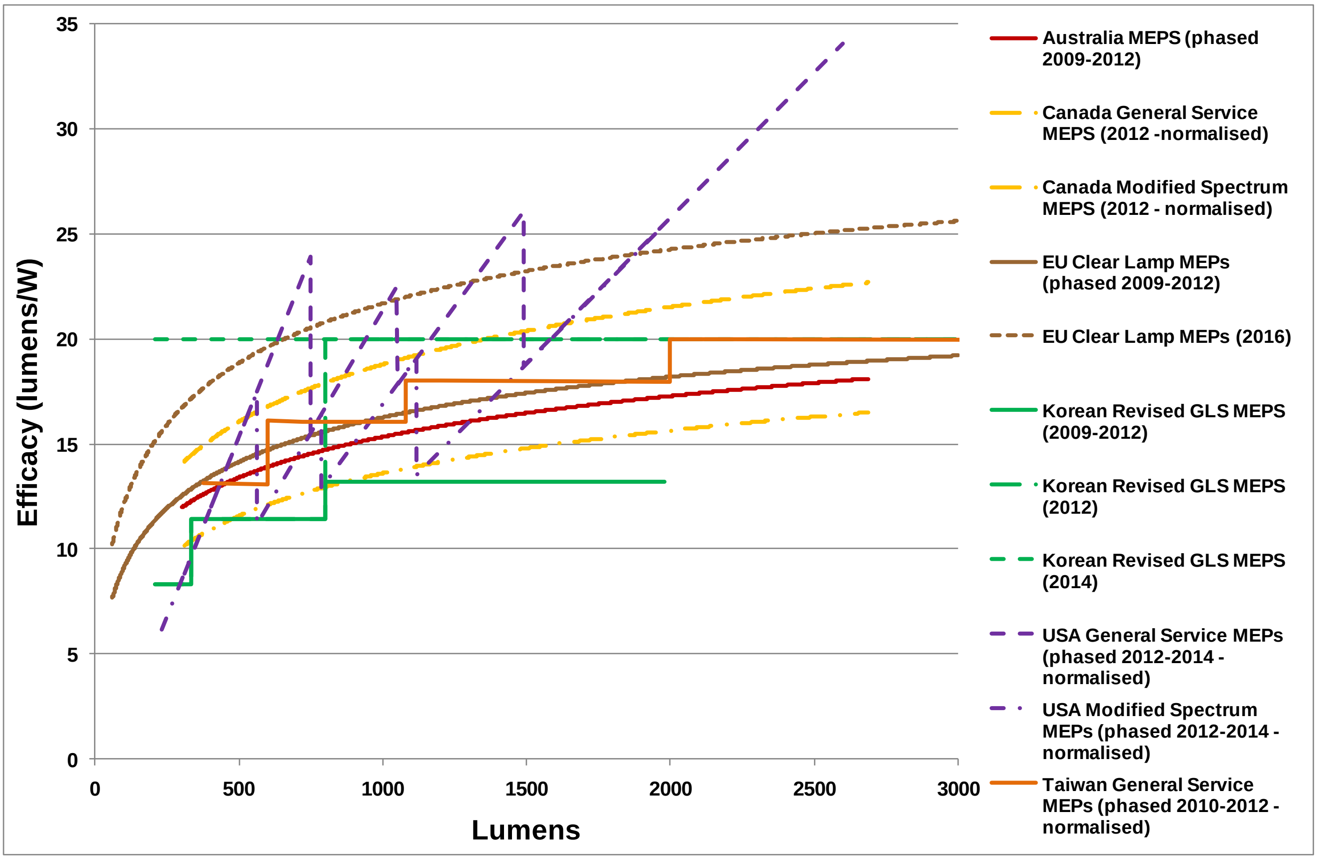
2.1.3 Stringency and timing of regulatory requirements

Figure 8 shows the overall stringency of requirements (i.e. the minimum performance levels) for all known current and future regulations for 'general lighting lamps' in reporting countries.[28][29] As can be seen, the overall requirements differ markedly. Part of this difference is due to the phasing (or staging) of the introduction of regulations and the

[28] All reporting countries have defined a minimum requirement for 'general lighting lamps'. However, there are indications that some countries developing regulations at the present time may *not* allow such 'general lighting lamps' at their current efficacy levels. There are indications that these countries may mandate lamps of efficacies similar to the requirements of the USA in 2017 (see footnote 29 below) or at a level that will require all lamps to be at least as efficient as the current generation of CFLs.

[29] Note that the USA has an additional requirement that new rules must be in place by 2017 (for implementation no later than 2020). These rules require a minimum average efficacy of 45 lm/W. Should such a rule not be put in place, a default requirement of 45 lm/W becomes mandatory on *all* non-reflector incandescent lamps. However, this requirement has been excluded from the graphic as the likely requirements of the regulations are not currently clear, and the rule making is not anticipated to begin prior to 2014. Please refer to the USA country mapping at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

Figure 8. Overall stringency of requirements for all known current and future regulations for 'general lighting lamps' in reporting countries.

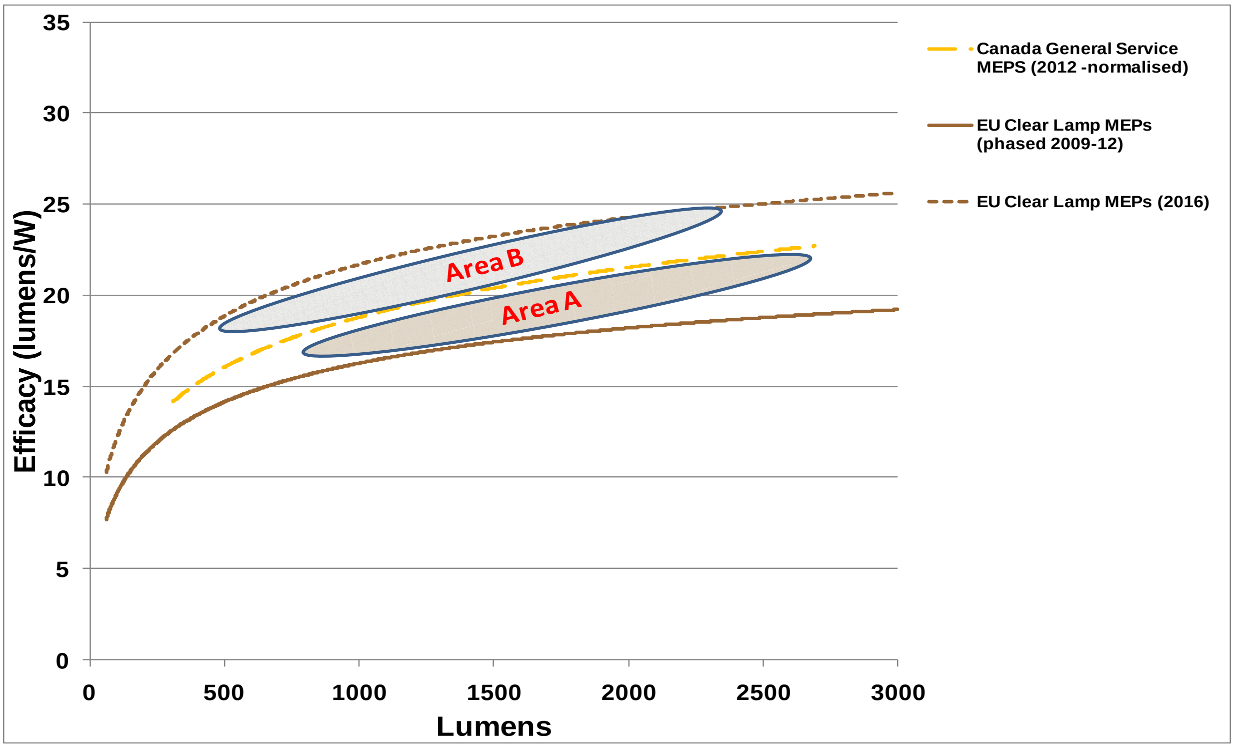


associated time for suppliers to react[30]. The clearest example of this is the two-step process being employed by the EU member states where the 2016 requirement is 33% higher than the 2012 requirement. Similarly, part of the difference may be caused by the additional performance requirements placed on lamps in some jurisdictions compared with others, and the associated efficacy trade-offs with such performance requirements (e.g. a requirement for a particularly long minimum lifetime *may* restrict the setting of a particularly challenging efficacy limit). However, this difference in phasing *appears* to be only partially the cause of the significant differences in efficacy requirements.

[30] Note that phasing is happening in two ways. Firstly there is the phasing of introduction of regulations over time (e.g. the introduction of the EU regulations between 2009-2012 for various lamp sizes). The second is phasing of the increased stringency of the overall requirement. Again using the EU as an example, this is the 'step' between the requirements in 2009-12 and those from 2016 onward. For clarity, the benchmarking primarily addresses the second type of phasing.

When normalised for the inherent difference in lamp performance between 110/120 V and 220/240 V lamps (and assuming a lamp output of 1000 lumens), the EU requirement will be approximately 15% lower than the requirement in Canada in 2012 when both regions' regulations are fully in place.[31,32] However, by 2016 the opposite situation will be true with the EU requiring a minimum efficacy 15% above that required for Canada (assuming the EU or Canada do not revise their requirements in the intervening time). Figure 9 demonstrates the potential savings that could be attained by the countries in the EU simply by adopting the

Figure 9. Potential savings that could be attained by adopting regulations in place elsewhere (EU and Canada).

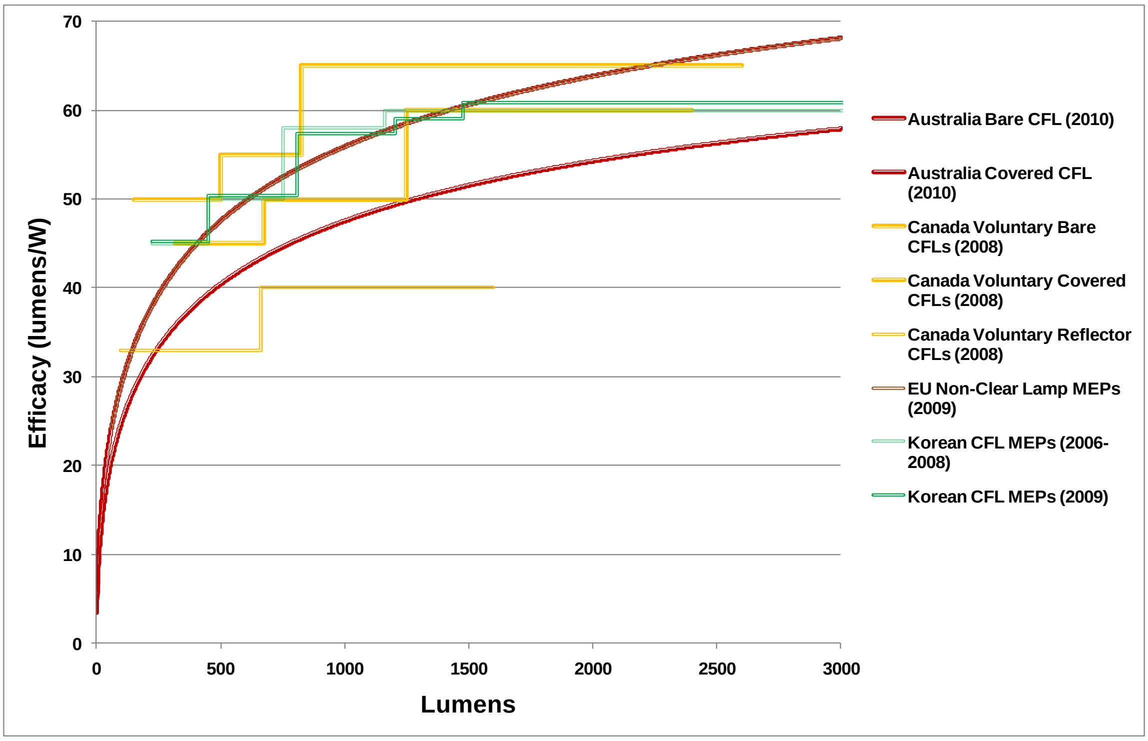


220/240 V equivalent of the requirements in Canada in 2012 (Area A). Area B on Figure 9 is the savings that could be achieved by Canada if it adopted the EU requirements in 2016. A similar but more complex picture emerges when comparing the regulations in other countries (e.g. the regulations due to come into effect in Korea in 2014 are significantly more stringent than any other country/region for lamps below 500 lumens, but significantly weaker for lamps above 1,000 lumens).

[31] It is worth noting that although there is apparently (approximately) 5% difference between the EU and Australian minimum efficiency regulations for 'incandescent' lamps, in practice these regulations are almost identical. with the difference primarily related to the relative interpretation of test standards and associated tolerance levels.
[32] This difference may partially be explained by countries with a supply voltage of 110-120 V being able to use Infra-red coated (IRC) lamp technology. At present, such technology cannot be applied to higher light output lamps operating on 220-240 V due to issues related to filament length and lamp stability.

Figure 10 illustrates a similar range of minimum efficiency requirements that exists for CFLs[33] (note that the Canadian CFL 'regulations' are voluntary but widely adopted in Canada[34]). A provisional investigation of additional minimum performance requirements placed on the lamps in EU member states, Australia and Canada (for example related to lifetime, colour, lumen maintenance, etc) indicates that these requirements are very similar. Hence, there appears little justification in the differences in minimum efficacy requirements between countries[35] and a realignment of regulatory performance requirements as a continuous curve broadly in line with the 2008 Canadian voluntary requirements would generate substantial additional savings for all countries and reduce the burden of compliance on manufacturers.

Figure 10. Comparative minimum efficiency requirements for CFLs (Canadian standards voluntary).



2.1.4 Lumen/wattage range of regulatory requirements

Almost all regulations have a limited minimum and maximum range in terms of lumen output or power, i.e. the regulations do not apply to 'small' or 'large' lamps. Figure 11 shows an expanded view of the lower limits for minimum efficiency for regulated lamps. At this lower end, the regulations encompass lamps no lower than 25 W[36] (approximately 300 lm) in

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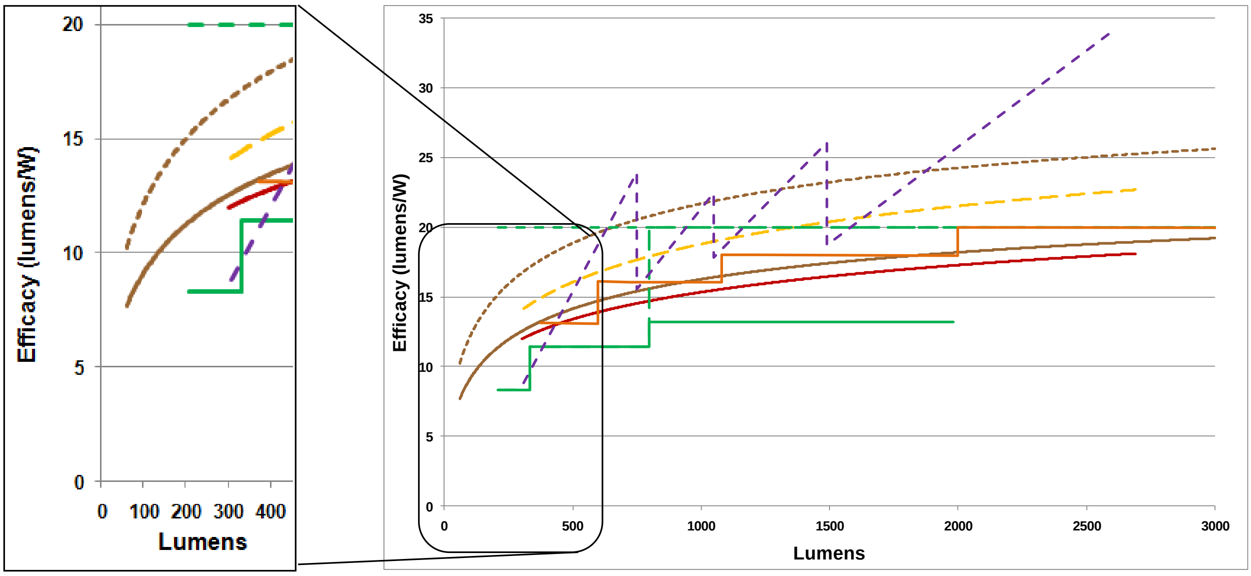
[33] No normalisation is required as the efficacy of CFLs is similar at 110/120 V and 220/240 V due to the electronics which are an integral part of the product.
[34] Although Canada's 2008 requirements for CFLs are currently voluntary, the Canadian Government reports that in 2010 over 90% of CFLs complied with the requirement and thus there is no apparent problem with the ability of the market to comply should a minimum performance level be set at a broadly comparable level.
[35] Other than the difference between the inherently less efficient covered lamps when compared with bare lamps.

Australia and 250 lm (approximately 22 W[36] standard incandescent) in Canada; down to 60 lm (approximately 7 W[36] standard incandescent) in the EU member states. A similar situation exists for the upper end of the regulations where the limits are 2,600 lm in Canada and the USA, 3,000 lm in Korea, and 12,000 lm in the EU member states. Where regulations exist for CFLs, a similar pattern is followed with only Australia and the EU member states having similar lumen/wattage scopes.

Figure 11. Expanded view of lower limit of regulations.



While part of these differences may be accounted for by differences in lamps included/exempted from the regulations (see Section 2.1.5), it appears unlikely that exceptions account for all the difference.

Further, as currently formulated, the regulations in Canada, Korea and the USA carry a risk. When regulations come into force, the consumers currently using lamps close to the upper and lower ends of the regulatory requirements may switch to slightly larger or smaller lamps that fall outside the regulatory limits. Clearly this bypasses the regulatory requirements and *may* confound policy maker intentions. While it is noted that there are currently no reports of such actions occurring in the market, alignment of the lumen/wattage scope with the EU would alleviate the risk.

So again, there is an opportunity to align limits to the lowest and highest levels (that of the EU member states) in order to capture the most number of lamps in the regulations and maximise the saving potential.

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[36] In practice, for countries that use continuous curves for regulation, these approximate comparable wattages are higher than stated as less efficient lamps will have lower lumen outputs than required by the regulations and, as such will fall below the lower lumen limit of the regulations.

2.1.5 Lamp inclusions and exemptions from regulatory requirements

All the regulations reported (except possibly Korea and Taiwan) have exemptions for various lamp types. Such lamp types are typically for specialist applications, e.g. lamps designed for airport runways, shock and vibration resistant lamps for hostile environments, lamps for appliances, etc. In some cases entire lamp categorisations are excluded. Again, while *broadly* similar, these exemptions vary significantly at the very detailed level with a large number of lamp types excluded in some countries, and a much smaller group of exclusions elsewhere. Clearly many of these differences are due to cultural, historical and technical differences[37] associated with lamp use within different countries. In principle, such variations should be of no concern if appropriate for local conditions. However, such differences create two potential risks:

1) At the very detailed level, the exclusions are very different between the various locations. Such difference has the *potential* to cause confusion for suppliers. This confusion may lead to inadvertent supply of non-compliant lamps to some markets and/or the unnecessary restriction of supply of certain lamp types to other markets (with the associated reduction in competition and/or shortages of lamps for some applications).

2) There is a potential that exemptions *may* lead some suppliers to use the opportunity to slightly alter the technical specification (or indeed in some cases just the declared type) of their products to avoid compliance with *the spirit* of the regulations. Perhaps the simplest example to demonstrate such an *opportunity* is the difference in requirements for 'standard' lamps and 'modified spectrum' lamps in the US[38]. Figure 12 shows the efficacy requirements for 'normal' and 'modified spectrum' incandescent lamps in the USA. As can be seen, for some lumen levels the modified spectrum requirement is 30+% below the requirement for normal incandescent producing similar quantities of lighting. Thus, the *potential* exists for suppliers to coat non-compliant lamps to slightly modify the spectrum and continue to market the product to the same consumer target groups as prior to the regulatory requirement (although potentially with differing packaging requirements).

   Other examples where suppliers may be tempted to follow similar product modifications include the coating of a 'normal' lamp in such a manner to enable the

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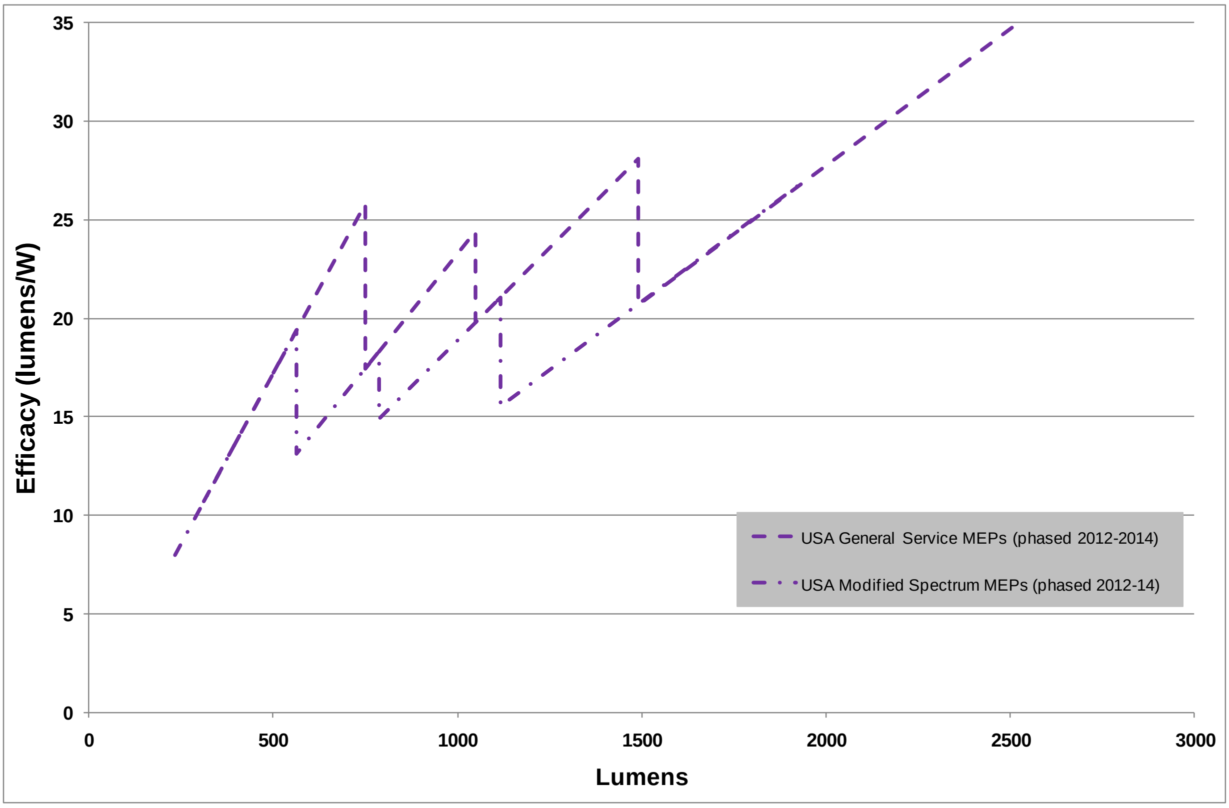
[37] For example, the historical and technical barriers that sometimes arise are amply demonstrated by a particular sort of dimmer switch in very common use in Australia but also seen in North America. This dimmer relies on current leakage which means the majority of CFLs will not operate on the circuit.

[38] In the USA modified spectrum lamps typically have a coating on the outside of the lamp which removes some elements of the colour spectrum. Such lamps are reported by some consumers to provide lighting which is less physically/psychologically stressful for reading and typical 'office work' and to give preferred illumination to some decorative fittings. (Note Canada also differentiates 'standard' and 'modified spectrum' lamps – however, Canadian regulations are formulated such that the spectrum can only be modified by coating if an infra-red halogen lamp is used). It is important to note that in neither Canada or the USA are these regulations *technically* an exemption, but are similar, and their use in the text is to enable the *principle* to be clearly demonstrated.. It should be further noted that, even the less challenging 'modified spectrum' requirements in the USA are still higher than the minimum requirement for lamps in the EU member states for a number of lumen ranges.

lamp to be classified as shatter resistant, or simply the renaming of a lamp to one of the excluded categories (e.g. plant life lamp).

Figure 12. USA requirements for 'normal' and 'modified spectrum Incandescent' lamps.



Again, at present there is no evidence of supplier confusion and/or deliberate actions to circumvent the spirit of the regulations in place. However, policy makers should be aware of the potential and remain vigilant in case such issues arise[39].

One final note on the inclusions and exemptions. In contrast to most other countries, the European Union has set a 2009 minimum requirement for non-clear lamps (i.e. all covered CFLs and 'frosted' lamps that do not provide a point source illumination[40]). This requirement is technology neutral, but has the effect of requiring all non-clear lamps to be of an efficacy equivalent to a covered CFL. The apparent logic of this decision is that a CFL provides an excellent non point-source light, and therefore it should be the minimum requirement for all lamps providing such a service. While such lamps have limited penetration in many markets, policy makers may want to consider aligning with this requirement as there are significant potential savings to be made with no apparent adverse consequences.

[39] In Canada, the market is being protected from such circumvention by regular review of exemptions to ensure no efficient alternative is available and by requiring exempt product to pass third-party certification to show they meet the definition in question and be labelled as being for a specific application.
[40] For precise definition of a non-clear lamp please refer to the EU mapping sheet at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

2.1.6 Other policy actions supporting the improved lighting efficiency

Although the primary focus of this benchmarking is the regulatory policy interventions related to the phasing out of inefficient lighting products, a number of other policy actions are currently (or have been) in place that will have an effect on the apparent outcomes of the regulatory policies. In particular, most countries have strong promotional, labelling, financial support mechanisms and/or building codes which have directly or indirectly supported the adoption of higher efficiency products (in particular CFLs and more recently LEDs).[41]

In addition the UK voluntary agreement[42] with retailers to 'phase-out' most inefficient domestic lighting between 2007-2010, i.e. slightly in advance of the requirements adopted by most other EU member states, appears to have offset a negative market movement elsewhere (see Section 3.2.1).

Other actions, such as US Department of Energy's support for the development and adoption of LEDs, and the early adoption of regulations by California, may have had additional impact on the market, but from the data available, such impact is not known.

2.1.7 Enforcement and impact

One final issue that is of relevance to all regulatory regimes is the associated enforcement and the measurement of impact of the regulations. Clearly when enforcing regulations in the market place it is the *actual measured* efficacy of the *individual* lamp that is being imported, sold, etc that is of importance. However, when considering the *impact* on the market, the *average efficacy of all lamps* sold is the most appropriate measure, not the *average of the sum of lamp efficacies.*[43] While a true indication of impact requires knowledge of usage patterns and the lamps being replaced, considering the *average efficacy of all lamps* sold gives an indication of the likely direction of changes in *consumption* (by taking into account potential changes in consumer preference for the size/power of the lighting products they are selecting). The average of all lamp efficacies sold provides almost no useful knowledge of market impact.

2.2 Key issues for policy makers

Despite the large variety of sizes, shapes, colours, caps, etc, lamps are *the* most globally traded energy consuming product. Further, given the vast array of products available on the market, it is the product group with the least technical difficulty in complying with local cultural and technical requirements. Given the global picture of the supply, and the evidence

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[41] While excluded from the scope of this study, it is worth noting that many countries/regions have had highly successful programmes targeting fluorescent tubes. Many countries are in the process of banning the sale of T12 tubes (Korea did so before 2007). Further, market penetration of T5 tubes is rapid in a number of markets.
[42] Between 2004-2010 utilities in the UK also distributed in excess of 300 million CFLs as part of the CERT (Carbon Emission Reduction Targets).
[43] The (sum of all lumens sold)/(sum of all wattages sold) **not the** (sum of efficiencies of all lamps sold)/(sum of lamp sold). This is because in the first equation lamps with higher wattages (and hence energy consumption) have a greater impact on the overall resulting average efficacy, rather than all lamps having equal weighting irrespective of consumption as is the case in the second equation.

that all current or pending regulatory requirements can be met by suppliers, the alignment of regulatory requirements between jurisdictions should be technically *relatively* simple if the political environment allows. Such an alignment of requirements would:

- Enable the realisation of substantial additional energy savings. Simply the adoption of the most stringent performance requirements and product scopes *that are currently in place or will imminently come into force* in participant countries would result in an increase in the stringency of existing requirement of over 15% in most participating countries (i.e. the adoption of incandescent requirements broadly in line with those specified in the EU for 2016, and voluntary CFL requirements from Canada in 2008[44]);
- Enable better supplier understanding and compliance with requirements of regulations in all countries;
- Enhance the potential for local and cross border enforcement actions;
- Facilitate increased global trade and *potentially* reductions in cost to the consumer.

Similar opportunities exist through the alignment of the various 'scopes and exclusions', e.g. general adoption of the EU requirement for CFL equivalent efficacies for all non-clear light sources.

If together such actions yielded an average of ***just 1 watt additional saving*** per lamp, when the 6,682 million incandescents installed in the EU 27 countries and the USA[45] are replaced, this would conservatively yield additional savings of over 2.4 TWh/year or approximately 1.95 million tonnes/year of avoided CO_2 emissions[46]. However, this saving is actually likely to be *much* higher in these regions. Further, given the size of these trading blocs, such harmonisation would send a powerful signal to other countries on the levels of ambition possible, and the benefits in reduced energy consumption (and increased trade) from harmonisation.

Due to the difficulty in revising regulations in a number of jurisdictions, such harmonisation of action is unlikely to be possible during the implementation of current regulatory requirements. However, policy makers should remain aware of the opportunities when these requirements are revised in the future. Further, a more immediately opportunity is presented as test methods and regulatory requirements are developed for LEDs. International coordination of action at this early stage of market penetration (such as that started under the 4E SSL Annex and elsewhere) has the potential to yield dramatic benefits for the

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44 Although Canada's 2008 requirements for CFLs are currently voluntary, the Canadian Government reports that in 2010 over 90% of CFLs complied with the requirement and thus there is no apparent problem with the ability of the market to comply should a minimum performance level be set at a broadly comparable level.

45 Total installed non-reflector incandescent lamps in the USA in 2002 was 3,912 m (Table 5-4 *Inventory of Lamps in the US by End-Use Sector; US Lighting Characterisation*. Office of Energy Efficiency and Renewable Energy, US Department of Energy, September 2002). Total installed incandescent lamps in the EU 27 in 2007 was 2,770 m (REMODECE survey Table 2.11: *Preparatory Studies for Eco-design Requirements of EuPs*, Lot 19: Domestic lighting, Part 1 - Non-Directional Light Sources, Final task report, Task 2: Economic and Market Analysis).

46 Assuming the 6,682 million lamps save 1 W and operate for an average of 1 hour per day for each day of the year. CO_2 emissions factor assumed to be 0.8kg of CO_2 per 1 kWh of electricity consumed.

consumer through wider choice of high quality products and for reductions in emissions in the medium term[47].

At the very least, policy makers should be aware of the issues that could affect the desired outcomes of their policies as they become effective in local markets. As it appears that *technical* compliance and compliance with the *spirit* of the regulations should be relatively easy in all regions, policy makers may wish to ensure that sufficient market monitoring is in place to quickly identify if:

- There is a significant increase in sales of lamps falling outside the lower or upper lumen or wattage limits of the regulations. This would indicate consumers are switching to smaller or larger lamps rather than adopting the more efficient alternatives as intended by the regulations;

- There is a significant increase in the sales of lamps that are excluded from regulations, or that are subject to relaxed requirements (e.g. reflector, shatter resistant or modified spectrum lamps). Such an increase in sales is *likely* to indicate suppliers are bringing products to market that are modified in some way (either technically or by declaration) thus enabling the sale of existing products that confound the intent of the policy.

Where policy makers are unable to monitor the impact on actual consumption in their market through full stock models, they may wish to do so through monitoring of the efficacy of sales. However, if this is the case, it is important to do so through the monitoring the *average efficacy of all lamps* sold, not the *average of the sum of lamp efficacies.*[48]

[47] Such coordination is beginning to happen through the 4E Annex dedicated to Solid State Lighting, the UNEP/GEF En.Lighten Project and similar actions in APEC and within the IEC. However, these actions are relatively slow and there appear to be opportunities for further collaboration/harmonisation between these activities.

[48] The (sum of all lumens sold)/(sum of all wattages sold) **not the** (sum of efficiencies of all lamps sold)/(sum of lamp sold). This is because in the first equation lamps with higher wattages (and hence energy consumption) have a greater impact on the overall resulting average efficacy, rather than all lamps having equal weighting irrespective of consumption as is the case in the second equation.

3 Impact of regulations

3.1 Observations

3.1.1 Introduction to interpretation of lamp sales data

As noted in Section 1.2, any change in sales does not *necessarily* represent the equivalent change in stock as markets in most countries are in transition. This transition is causing consumers to switch between different lamp types and sizes, and the efficacy, performance and lifetime of the various lamp types is very different. To illustrate the complexity this introduces, consider a hypothetical example of a country with just 1,000 lamp sockets all of which are initially filled with incandescent lamps (the initial stock):

- If the 1,000 installed incandescent lamps have operational lives of 1 year, at the end of the first year when these lamps fail[49] consumers may replace the failed lamps with 900 incandescent lamps of the same lifetime, plus 100 CFLs of equivalent light output but of 10 years operational life. In this first year, lamp sales match the change in the occupancy of the 1,000 sockets left vacant by the failed Incandescent, i.e. 100 CFLs and 900 Incandescent. Because of the equivalency of light output, total lighting levels remain the same.

- In the following year, given the 1 year operational lifetime of the Incandescent, all 900 will again fail, but no CFLs will fail (due to their 10 year operational lives). So, only 900 lamps will need replacing. If replacements follow the same ratio as year 1, i.e. 90% incandescent and 10% CFL, then the sales will be 810 incandescents and 90 CFLs. Thus the ratio of sales remains the same: the total delivered light output remains the same; but total sales have fallen by 10%. Penetration of CFLs in the stock has risen to 19%.

- All things remaining equal, sales in year 10 would be just 349 incandescents and 40 CFLs but the level of lighting provided will still be the same.

- In year 11 the initial CFL purchased in year 1 would need replacing. However, by this time CFLs would be in place in 650 of the 1,000 sockets. Year 11 sales will be replacement of the 349 incandescent lamps by 314 incandescent lamps plus 35 CFLs; plus the original 100 CFLs from year 1. Throughout, light levels have remained constant, but lamp sales have been consistently falling until year 11 when there is a slight rise. Final installed stock at the end of year 11 is 314 incandescent lamps, and 686 CFLs.

However, despite a very simple example with just two lamp types and detailed knowledge of how sales will develop over time, we have no knowledge of the actual usage patterns of the lamps, their rated wattages, etc. Thus we are not able to make projections on initial energy

[49] Note that this example is hypothetical – lamp failures are obviously more complex in real life.

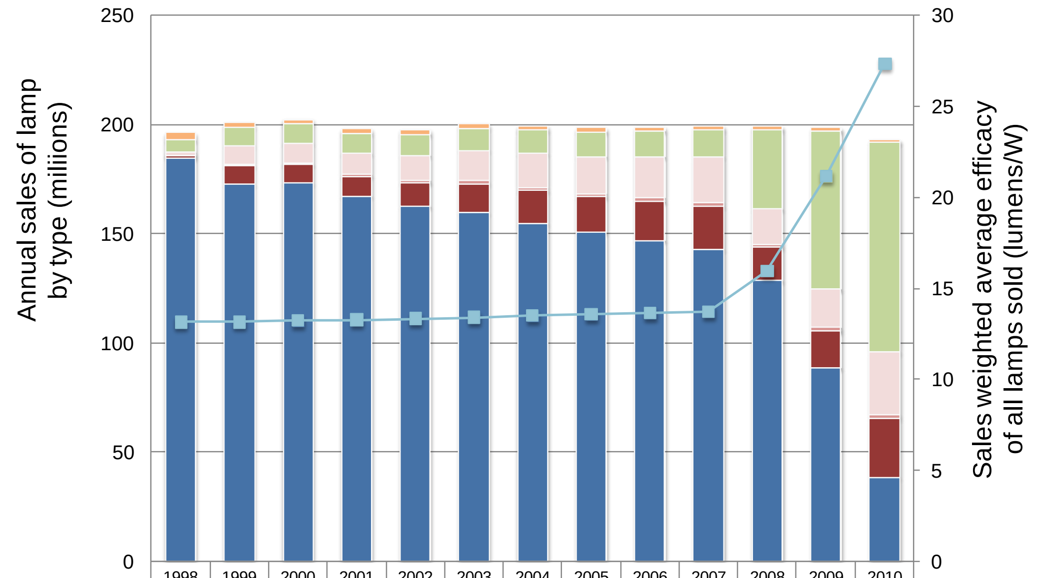
consumption of the stock or the likely future energy savings from the CFL installations. The best that can be achieved is an indication of the direction that stock efficiency will be taking (in this case clearly improving as CFLs replace incandescent, but we do not know to what degree).

Unfortunately, the real life situation is significantly more complex than the example, and the data available in this analysis are limited to sales of lamps by type, some knowledge of the rated wattage of those sales, and estimates of lamp lifetime.[50] Therefore, how can these data inform our original aims of:

- Understanding whether there are any major outcomes of the various policy implementations to date; and
- Gaining an indication of longer term efficiency improvements of the installed stock?

Figure 13 shows a time series of the sales of different lamp types in the UK. As can be seen, total sales of lamps have been approximately stable for the last 10 years, with a slight fall in the last two reporting years. This is consistent with the increasing sales of CFLs in preceding years, just as in our example.

Figure 13. Time series sales of lamp types and sales weighted efficacy of lamps in the UK.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
MV* Linear Fluorescent Tubes	3.5	2.2	2.1	2.1	2.1	2.0	2.0	1.9	1.8	1.6	1.5	1.3	1.1
MV* CFLs	5.6	8.3	8.8	9.3	9.7	10.2	10.7	11.3	11.9	12.4	36.5	72.6	96.0
Low Voltage (12V) Halogens	1.4	8.8	8.9	9.5	11.5	14.0	15.6	17.0	18.8	20.8	16.1	17.7	28.7
MV* Halogens (double ended)	0.1	0.8	0.8	0.8	1.0	1.2	1.4	1.5	1.7	1.8	1.4	1.6	1.7
MV* Halogens (single ended)	1.3	8.4	8.6	9.1	11.0	13.4	15.0	16.3	18.0	19.9	15.4	16.9	27.4
MV* Incandescents	184.6	172.7	173.3	167.3	162.5	159.7	154.8	150.7	147.0	142.9	128.5	88.6	38.3
Ave. product efficacy (lumens/W)	13.1	13.2	13.2	13.3	13.3	13.4	13.5	13.6	13.6	13.7	15.9	21.2	27.4

[50] Refer to Annex 2 Wattage buckets, standard efficacy tables, standard lifetimes and normalisation of lamps on differing voltages.

However, from this limited information (plus information on the rated wattage of sales in the UK mapping document[51]), we are able to learn the following:

- **Lamp types:** In the years from 1998 to 2007 there is a gentle migration in sales from incandescent lamps primarily to halogen (halogen sales growing from 1% to 22% of total annual sales), and a slower migration to CFLs (CFL sales growing from 3% to 6% of total annual sales). In 2008-2010, there is a marked shift in the pattern of lamp switching with the majority of movement from incandescent to CFLs (CFL sales increasing from 6% of total sales in 2007 to 50% of total sales in 2010), with a continued, but slightly accelerated growth in the sales of halogens.

- **Efficacy of lamp sales:** Between 2007 and 2010, this change in sales has resulted in an increase in the efficacy of lamps sold from 13.3 lm/W to 27 lm/W. This compares with a much smaller increase in efficacy of 12.5 lm/W to 13.3 lm/W over the longer 1998 to 2007 period.

- **Timing and types of market changes in relation to policy intervention:** The pan-EU regulations restricting the sale of incandescent lamps were formally announced in 2009 with initial restriction on the sale of larger inefficient lamps beginning in 2010. However, as noted in Section 2.1.6, the UK had reached a voluntary agreement with retailers to restrict the sale of inefficient lamps from 2007 onwards, in effect bring the entire European level timetable forward for the majority of retail outlets.

Given the strong alignment of the timing of policy action with significant changes in the market in the UK, it is reasonable to infer answers to our original questions as follows:

- *Have there been any major outcomes of the various policy implementations to date?* The combined voluntary agreement and EU regulations have had a direct and robust impact on the UK market for lamps, with the sales weighted efficacy of lamps more than doubling compared with the business as usual path prior to the announcement of the voluntary agreement in 2007.

- *Is there an indication of longer term efficiency improvements of the installed stock?* With some confidence it can also be asserted that the lamps being replaced in the stock will have a lower average efficiency than those recently purchased. This is evidenced by the relatively stable sales of lamp type (and their associated efficacy levels) prior to 2007, combined with the large number of relatively inefficient, short lifetime incandescent lamps that constituted the majority of sales prior to 2007 (hence these inefficient lamps will be the majority of lamps being replaced in the post 2007 sales). Thus, the overall average efficacy of stock will be increasing at a rate more rapid than the increase in efficacy of sales, although by what rate is unknown.

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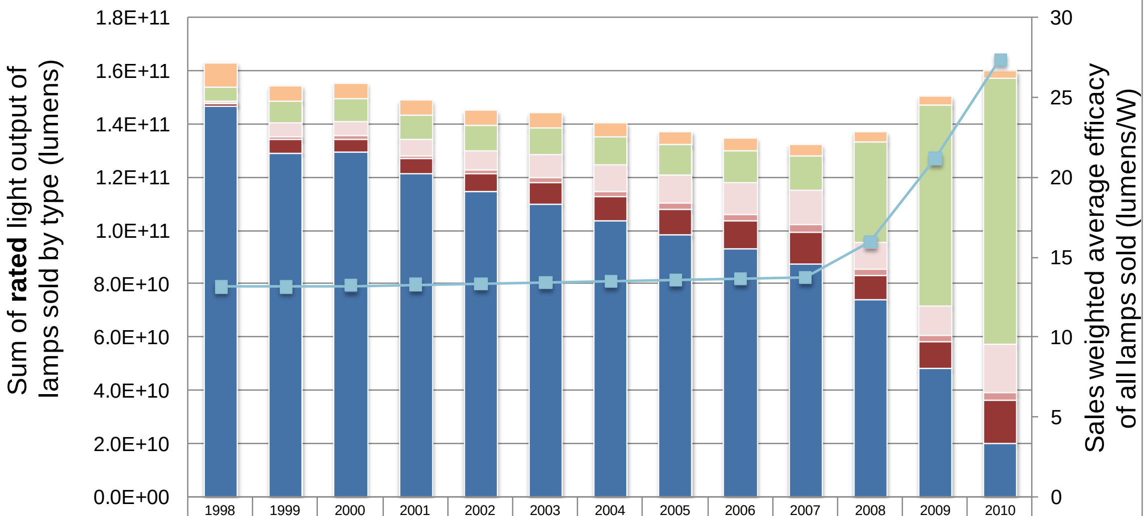
[51] See http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

Section 3.2.1 follows the same logical approach to understanding whether there has been any impact of policy on the market. However, because of the large differences in the absolute number of total lamp sales between individual countries, Section 3.2.1 examines the sales of each type of lamp as a *percentage* of total lamp sales in each market. This enables a comparison between countries of the changes in market share of individual lamp types over time. In parallel it is possible to analyse changes in average efficacy of sales and to provide detailed observations relating to individual countries where appropriate.

However, before moving to Section 3.2.1, there is one more observation from the UK specific example that applies to all countries under review. Figure 14 refers to the same UK lamp sales, but provides an approximation of their sales weighted instantaneous light output (or sum of the rated light output of lamps sold). Broadly speaking, Figure 14 shows us that the lamps being purchase over the period 1998-2010 are providing *similar* levels of total illumination as the lamps they are replacing, even allowing for slight increases in the number of sockets per household and the total number of households[52].

On its own this information is not particularly useful. However, the knowledge that lighting levels per lamp purchased are remaining relatively constant can be combined with the

Figure 14. Time series instantaneous light output of all UK sales.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
MV* Linear Fluorescent Tubes	9.3E+09	5.8E+09	5.7E+09	5.7E+09	5.6E+09	5.5E+09	5.4E+09	5.1E+09	4.8E+09	4.4E+09	4.0E+09	3.5E+09	3.0E+09
MV* Self-Ballasted CFLs	5.4E+09	8.1E+09	8.6E+09	9.2E+09	9.7E+09	1.0E+10	1.1E+10	1.1E+10	1.2E+10	1.3E+10	3.8E+10	7.5E+10	1.0E+11
Low Voltage (12V) Halogens	8.3E+08	5.4E+09	5.5E+09	5.8E+09	7.1E+09	8.6E+09	9.7E+09	1.1E+10	1.2E+10	1.3E+10	1.0E+10	1.1E+10	1.8E+10
MV* Halogens (double ended)	1.9E+08	1.2E+09	1.2E+09	1.3E+09	1.6E+09	2.0E+09	2.2E+09	2.4E+09	2.7E+09	2.9E+09	2.3E+09	2.5E+09	2.7E+09
MV* Halogens (single ended)	7.6E+08	4.9E+09	5.0E+09	5.3E+09	6.4E+09	7.9E+09	8.8E+09	9.6E+09	1.1E+10	1.2E+10	9.2E+09	1.0E+10	1.6E+10
MV* Incandescents	1.5E+11	1.3E+11	1.3E+11	1.2E+11	1.1E+11	1.1E+11	1.0E+11	9.8E+10	9.3E+10	8.8E+10	7.4E+10	4.8E+10	2.0E+10
Ave. product efficacy (lumens/W)	13.1	13.2	13.2	13.3	13.3	13.4	13.5	13.6	13.6	13.7	15.9	21.2	27.4

[52] The total rated light output of sales has actually been falling slowly between 1998 and 2007, with a more rapid increase over the most recent 3 years to a level slightly above the original 1998 level. However, broadly speaking, the total light output of the lamps purchased has remained stable.

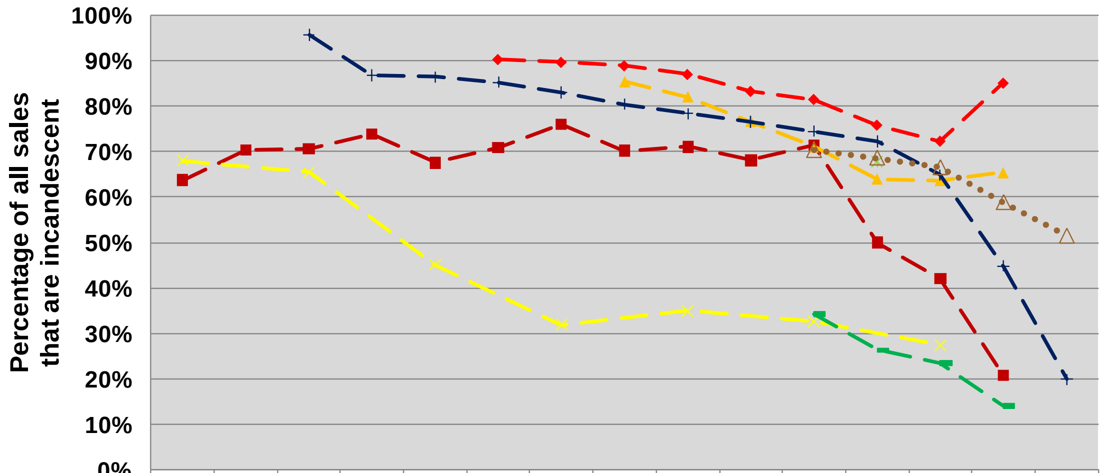
knowledge that more recent lamp sales have a significantly higher proportion of longer lifetime lamps (CFLs and Halogen lamps combined making 72% of all sales in 2010). As the longer life lamps will need replacing much less frequently than the shorter lifetime incandescent lamps currently dominating the stock, it is clear that demand for replacement lamps will soon begin to fall rapidly as the existing stock is replaced by the longer lasting lamps. Without a full model of the installed stock it is impossible to predict accurately what the ultimate levels of sales will be, but an *estimate* is that lamp sales in 2014 will be approximately 25% of those in 2009 if current trends continue.

3.2 Time series view of type of lamp sales in participating countries, efficacy changes and policy impacts

3.2.1 Changes in sales by products

Figure 15, Figure 16 and Figure 17 respectively show time series sales of incandescent lamps, sales of halogens and sales of CFLs as percentages of the total lamp sales in each country/region. Figure 18 shows changes in the average efficacy of those sales in the same periods.

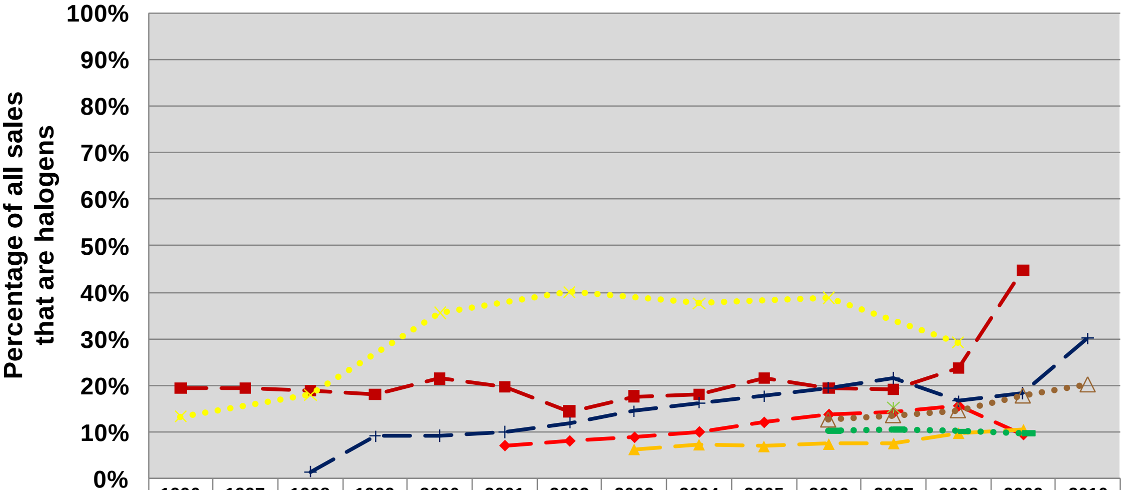
Figure 15. Percentage of all domestic lamp sales that are incandescent.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	64%	70%	71%	74%	68%	71%	76%	70%	71%	68%	71%	50%	42%	21%	
Austria						90%	90%	89%	87%	83%	81%	76%	72%	85%	
Canada								85%	82%	77%	71%	64%	64%	65%	
Denmark	68%		65%		45%		32%		35%		33%		27%		
France												68%			
Republic Of Korea											34%	26%	23%	14%	
United Kingdom			96%	87%	86%	85%	83%	80%	78%	77%	75%	72%	65%	45%	20%
EU											70%	69%	66%	59%	52%

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

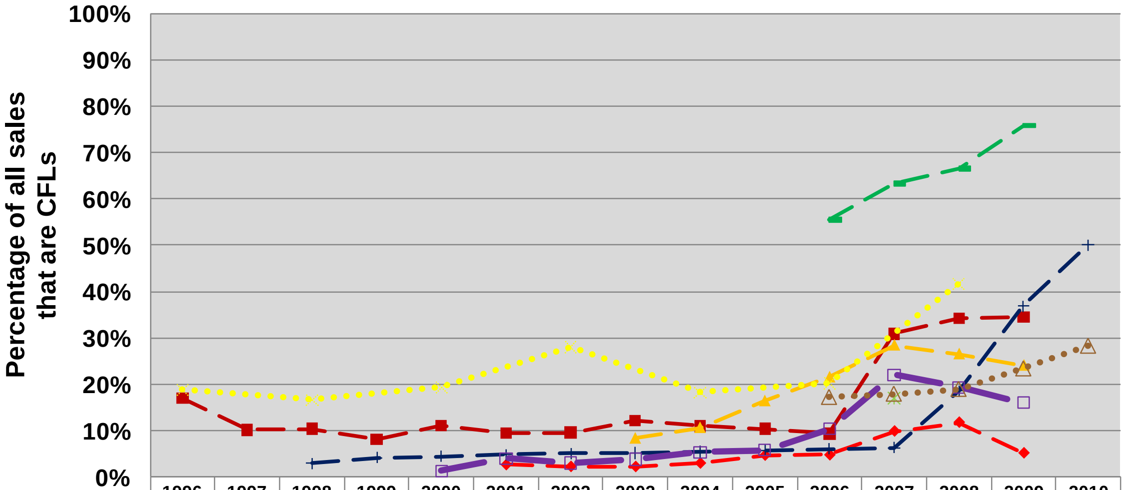
Figure 16. Percentage of all domestic sales that are halogen lamps (all halogen types).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	19%	19%	19%	18%	21%	20%	14%	18%	18%	22%	19%	19%	24%	45%	
Austria						7%	8%	9%	10%	12%	14%	14%	16%	9%	
Canada								6%	7%	7%	7%	8%	10%	11%	
Denmark	13%		18%		36%		40%		38%		39%		29%		
France												15%			
Republic Of Korea											10%	10%	10%	10%	
United Kingdom			1%	9%	9%	10%	12%	14%	16%	18%	19%	22%	17%	18%	30%
EU											13%	14%	15%	18%	20%

Solid line = robust data *Dashed line = indicative data* *Dotted line = illustrative data*

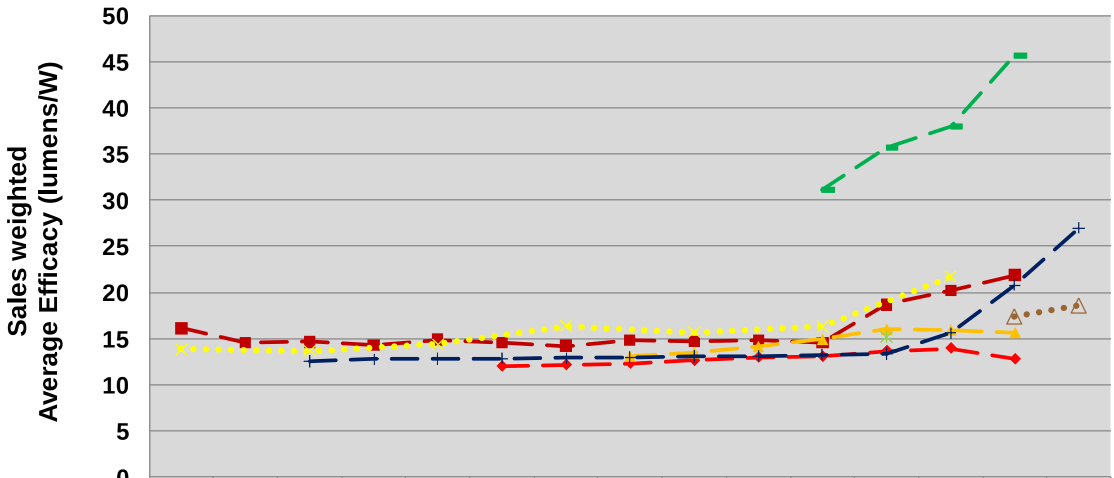
Figure 17. Percentage of all domestic sales that are CFLs (pin based and integrated ballasts).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	17%	10%	10%	8%	11%	9%	10%	12%	11%	10%	9%	31%	34%	34%	
Austria						3%	2%	2%	3%	5%	5%	10%	12%	5%	
Canada								8%	11%	16%	22%	28%	27%	24%	
Denmark	19%		17%		19%		28%		18%		20%		42%		
France												17%			
Republic Of Korea											56%	63%	66%	76%	
United Kingdom			3%	4%	4%	5%	5%	5%	5%	6%	6%	6%	18%	37%	50%
USA					1%	4%	3%	4%	5%	6%	10%	22%	19%	16%	
EU											17%	18%	19%	23%	28%

Solid line = robust data *Dashed line = indicative data* *Dotted line = illustrative data*

Figure 18. Time series sales weighted average efficacy of lamp sales by country/region.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	16.1	14.6	14.6	14.2	14.9	14.5	14.2	14.8	14.6	14.9	14.6	18.7	20.3	21.9	
Austria						12.0	12.2	12.3	12.6	13.0	13.0	13.6	13.9	12.8	
Canada								13.1	13.4	14.1	14.9	16.0	15.9	15.7	
Denmark	13.8		13.6		14.4		16.3		15.7		16.3		21.7		
France												15.1			
Republic Of Korea											31.1	35.7	38.0	45.7	
United Kingdom			12.5	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.3	15.6	20.8	27.0
EU														17.4	18.6

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

As can be seen in Figure 15, there is a very wide range in the market share of incandescents. However, prior to and including 2006, countries can broadly be brought together into two groups:

- *Austria, Australia, Canada, France, the UK and the EU:* All countries in this group have an incandescent market share between 70% and 96%. *Almost all* of these countries have shown a gradual decline in market share of incandescent lamps in line with the gradual market shift towards halogen lamps and CFLs shown in Figure 16**Error! Reference source not found.** and Figure 17 respectively. Canada has performed particularly well in this area with the percentage of sales of CFLs rising from 8% to 22% between 2003 and 2006. This significant boost aligns closely with the 2004 launch by National Resources Canada (and its partners - primarily utilities) of '*switch and save*', a major national promotional campaign targeted at encouraging consumers to switch to CFLs.

  The exception is Australia *where the sales o*f incandescent lamps have stayed relatively constant at the lower end of this range (70% of total sales). Evidence supplied by Australia and reproduced in its country mapping[53] suggests this is a cultural artefact with Australian buildings employing a high proportion of halogen reflector lamps (20% of sales) well before similar levels were reached elsewhere.

[53] See http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=5

However, in all cases, the average efficacy of sales has remained relatively stable in the 12.5-15lm/W range[54].

- *Korea and Denmark:* In 2006, both Korea and Denmark had proportions of incandescent sales around 33%, or approximately half the percentage of incandescent sales in all other countries.

  Denmark has been at this relatively low level of incandescent sales for a significant period (from 2004) having moved from 1996 level where incandescent sales were only slightly lower than the countries grouped above (68%). It is likely cultural factors and related consumer preference are the reason for the high penetration of CFLs in Denmark prior to 2000, (around 19% compared to most countries' 10% or less), and the rapidly increasing halogen lamp sales between 1996 and 2002. It is *assumed* cultural factors are the cause as there is no known strong policy action to cause either the stable CFL penetration or the rapid rise in halogen sales from 1996 onward. However, the significant spike in CFL sales between 1998 and 2004 (peaking at 28% of all lamp sales against an initial starting point of 17%) is *likely* to be as a result of the strong CFL promotion programme begun by the Danish Energy Saving Trust towards the end of the 1990s. This is considered likely as no other European country has a similar boost in CFL sales during this period. Whatever the ultimate cause, the end result was that Denmark maintained a sales weighted average efficacy only slightly better than that in Australia (starting just below Australia in 1996 at 13.5 lm/W, rising to slightly above Australia at 15.9 lm/W in 2006). This *appears* to be an illogical outcome as it would be expected the Danish sales weighted efficiency should be much higher given the penetration of CFLs and low sale of incandescents. However, the apparent cause is that Danish incandescent and halogen sales were, on average, of the more inefficient smaller wattages. Fortunately, because the length of time the CFL sales have been high in Denmark, it is *almost certain* that average efficiency of the *stock* will be significantly higher than the average of sales – but it is not known to what degree. Nevertheless, the Danish example serves to illustrate the risks with examining only sales and not impact in the stock.[55]

  In the case of Korea, there are no data preceding 2006 so it is not possible to reliably comment on the reason for its relatively low incandescent sales in this first reporting year. However, it does seem reasonable to note that Korea began regulating the efficiency of incandescent lamps much earlier than other countries (2003) and although this initial level was not particularly stringent, those regulations have been revised twice in the interim. By 2014, Korean regulations will be the most challenging in the world for smaller sized (the most inefficient) incandescent lamps – hence

[54] Efficacy of sales in the EU cannot be calculated for this period.
[55] By way of illustration of how careful it is necessary to be when considering the impact of sales of lighting products, if only considering the average efficacy of lamps sold (i.e., the sum of efficacies of all lamps/the total number of lamps sold), average efficacy for lamp sales in Denmark in 2006 was well over 20 lm/W in 2006, rising to higher levels in later years. This compares with the more representative value of 15.9 lm/W in 2006 derived from (Total lumens of all lamps sold)/(Total wattage of all lamps sold) used within the benchmarking.

sending a clear and strong message to the marketplace. Similarly, Korea has reported extensive promotion of CFLs over a long period, which *may* explain the CFL market shares significantly higher than anyone other country in 2006 (56% compared with the closest other country, Canada, at exactly half the Korean level). This relatively high penetration of efficient lamps is shown dramatically in the sales weighted efficacy of 31 lm/W, almost twice that of any other reporting country/region in 2006.

Post 2006, the picture changes very rapidly:

- **UK:** As noted in the introductory Section 3.2.1), it is reasonable to conclude that the fall in sales of incandescent and the doubling in the average efficacy of lamps sold in the UK from 2006 onwards is due to the combined EU level mandatory requirements and the national level voluntary agreement with retailers.

- **Australia:** A move in sales almost identical to that in the UK appears to be happening in Australia, i.e. a fall from 71% incandescent sales in 2006 to 21% sales in 2009 with a switch in the market to alternative CFLs and halogens. This market change aligns closely with Australia's announcement of phase-out plans in 2007/8 (stores reported selling out of CFLs within days of the initial announcement of the *intention* to regulate the market) and subsequently the prohibition of sales of most types of incandescent lamps. So again it seems reasonable to conclude there has been clear and direct market impact from the policy.

  However, compared with the UK there does appear to be a significant difference in the product switch. Sales of CFLs climb to 34% but then level (in both 2008 and 2009), while halogens have continued to accelerate growth from 19% to 45% between 2007 and 2009.[56] This *may* be of concern for policy makers if their original expectation was for a major market shift towards CFLs which afford significantly greater savings than the current generation of halogens[57] (note that the share of sales by different types of halogens is investigated in Section 3.2.2).

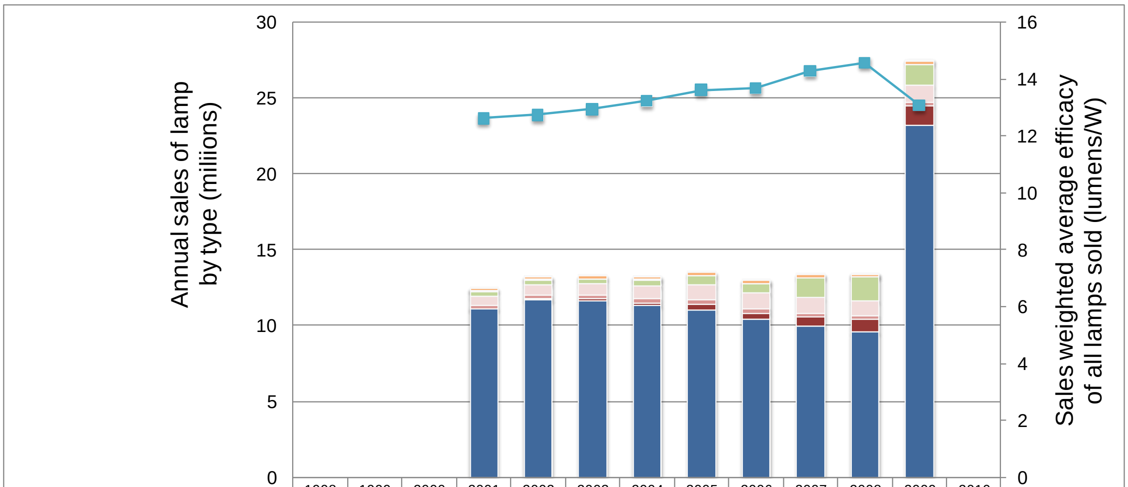
- **Austria:** Austria shows a somewhat differing pattern. The percentage of total sales of incandescents, halogens and CFLs (and the associated sales weighted efficacy) in Austria very closely shadowed those in the UK from the earliest reporting year through to 2007 (see Figure 19[58] and Figure 20). Therefore, as Austria is subject to the same mandatory EU legislation as the UK, it would be expected that there would be a market switch very similar to the UK (although approximately two years later as Austria does not have the same agreement with retailers which effectively brought

[56] Note that provisional 2010 data from Australia indicates that sales of mains voltage halogen lamps have also levelled at 2009 levels.
[57] As previously noted halogen sales that are higher than the sales of CFLs will not necessarily have a mirror impact on the make-up of stock due to the significantly longer lifetimes of CFLs. However, the exact outcome is not known from the data available.
[58] Note that Figure 20 does not show *actual* sales in Austria. The data supplied covers just 55% of the market, but the proportion of sales of each lamp type is believed to be representative of the entire market.

the EU legislation forward by two years in the UK). Indeed there was a major market movement In Austria in 2009, but in precisely the opposite direction.

From 2001 to 2008 the percentage of incandescent sales in Austria had fallen from 90% to 72% of total lamp sales.[59] The remaining sales were split approximately equally between halogen lamps and CFLs. This is entirely in line with expectations given experience elsewhere (and similar to the UK comparison shown). However, in 2009, the proportion of incandescent sales *rose* back to 85% of all lamp sales with an associated fall in sales weighted efficacy from 13.9 lm/W to 12.8 lm/W. Further investigation of this anomaly has revealed that, in this particular case, the use of percentage of total sales as a metric is not ideal.

Figure 19. Time series lamp sales by type in Austria.

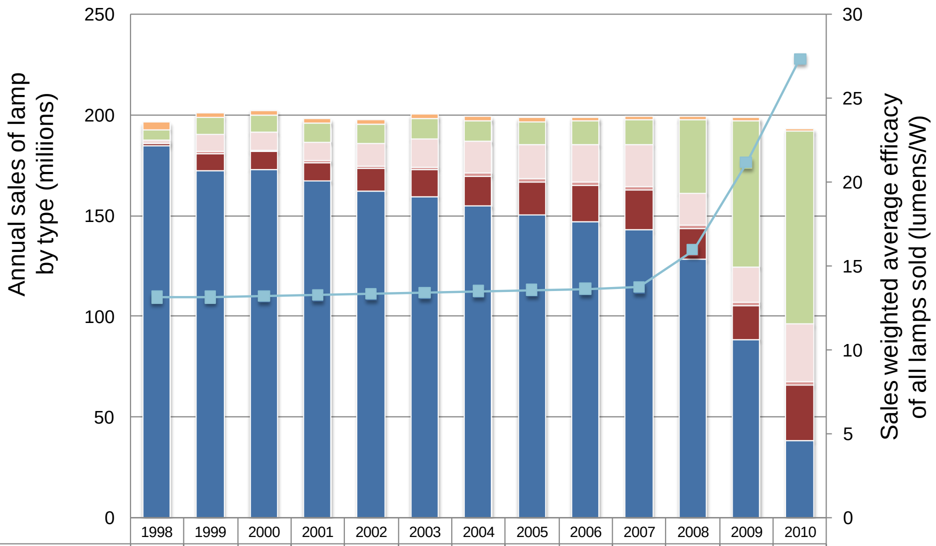


	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LED lamps										0.0	0.0	0.1	
MV* Linear Fluorescent Tubes (T12)				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MV* Linear Fluorescent Tubes (T8)				0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
MV* Linear Fluorescent Tubes (T5)				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MV* CFLs				0.3	0.3	0.3	0.4	0.6	0.6	1.3	1.5	1.4	
Low Voltage (12V) Halogens				0.6	0.7	0.8	0.9	1.0	1.1	1.0	1.0	1.1	
MV* Halogens (double ended)				0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	
MV* Halogens (single ended)				0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.8	1.2	
MV* Incandescents				11.1	11.7	11.6	11.3	11.1	10.4	10.0	9.6	23.3	
Ave. product efficacy (lumens/W)				12.6	12.7	13.0	13.2	13.6	13.7	14.3	14.6	13.1	

From Figure 19 it is clear that in 2009 total sales of halogen lamps have grown compared to preceding years and sales of CFLs have fallen but only very slightly. The striking element of sales in 2009 is the more than doubling of incandescent sales from 9.6 million to 21.3 million. Hence the fall in *percentage* sales of halogens and incandescents was not a result of an *actual* fall in sales of these products, but a sudden rise in the sales of incandescents. Discussions with the data supplier and with the Austrian Annex participant indicate that this sudden rise in the sale of incandescents was a result of very adverse publicity in 2009 related to the EU phase-

[59] Note that the Austrian sales reported represent only approximately 55% of all lamp sales in Austria. However, the data supply believes this is a representative picture of the whole market.

Figure 20. Time series lamp sales by type in the UK.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
MV* Linear Fluorescent Tubes	3.5	2.2	2.1	2.1	2.1	2.0	2.0	1.9	1.8	1.6	1.5	1.3	1.1
MV* CFLs	5.6	8.3	8.8	9.3	9.7	10.2	10.7	11.3	11.9	12.4	36.5	72.6	96.0
Low Voltage (12V) Halogens	1.4	8.8	8.9	9.5	11.5	14.0	15.6	17.0	18.8	20.8	16.1	17.7	28.7
MV* Halogens (double ended)	0.1	0.8	0.8	0.8	1.0	1.2	1.4	1.5	1.7	1.8	1.4	1.6	1.7
MV* Halogens (single ended)	1.3	8.4	8.6	9.1	11.0	13.4	15.0	16.3	18.0	19.9	15.4	16.9	27.4
MV* Incandescents	184.6	172.7	173.3	167.3	162.5	159.7	154.8	150.7	147.0	142.9	128.5	88.6	38.3
Ave. product efficacy (lumens/W)	13.1	13.2	13.2	13.3	13.3	13.4	13.5	13.6	13.6	13.7	15.9	21.2	27.4

out requirement about to come into force in 2010 (to paraphrase much of the media coverage, ‘the EU are banning our beloved lamps’). As a result, there *appears* to have been large scale consumer purchase of incandescent lamps for storage to replace lamps that fail after incandescents are no longer for sale from 2010 onward.

Assuming from 2010 onward sales are affected by the EU policy and there is a migration from incandescents to CFLs and/or halogens, such a ‘consumer store’ of incandescents should result in just a short delay in the full impact of the policy being felt as the ‘stored’ lamps are used and the post policy lamps begin entering the stock. However, such a delay may be significantly extended if consumers continue to buy in large stocks of smaller lumen/wattage incandescents which may still be available in 2010 and 2011. At the time of preparation of this report, data for 2010 are not available, so it is not possible to know whether such outcomes are occurring and whether the delay in policy impact will be short or extended.

Hence, it is currently not possible to draw conclusions on whether the EU lighting policy is being effective in Austria. However, there appears to be an important lesson for policy makers from the Austrian example. In particular, policy makers should be aware that a significant delay in the date regulations come into force after initial announcement can result in a market effect completely at odds with the intention of the policy action where the cost of the product is very low (it is difficult to image consumers ‘storing’ higher value larger goods such as washing machines or TVs in the same way). Thus, when regulating these low value, relatively high volume products, policy makers *potentially* need to be more aware of the balance between allowing time for the supply side to respond (and to allay issues such as stranded investment), compared with the adverse consumer response delaying the ultimate policy impact to a point well beyond the actual introduction of the policy.

- **Canada:** Sales of incandescents after 2006 have remained almost constant at 64%, with a slight overall migration to halogens from CFLs. This has resulted in sales of CFLs falling as a percentage of all lamp sales from 28% in 2007 to 24% in 2009, with a resulting fall in sales weighted efficacy from 16 lm/W in 2007 to 15.7 lm/W in 2009. Such a fall would be expected if much of the consumer desire to switch from incandescents to CFLs has been saturated, and current sales of CFL sales are the result of CFL replacement rather than switching from alternate products. This *may* be an indication that the switching to CFLs encouraged by 'switch and save' and ENERGY STAR has now peaked. There is certainly no current indication from lamp sales that the market is yet reacting to the regulations due to come into effect in 2012.

- **Denmark*:*** Post 2006 has seen a continued gentle fall in incandescent sales from 33% of total lamp sales in 2006 to 27% in 2008. However, unlike any other country/region covered in this report, sales of halogen lamps have fallen substantially over the same period (39% to 29% of total sales). The remaining market share has been absorbed by a sudden surge in CFL sales from 20% of all lamps sold in 2006, to 42% of all lamp sales in 2008. This has resulted in a rise of the sales weighted average efficacy from 15.9 lm/W to 19.7 lm/W in just two years between 2006 and 2008.This surge in CFL sales is a remarkable outcome bearing in mind the unusually high proportion of CFL sales (and hence installed lamps) compared to most other countries up to 2006. However, given the timing of the announcements and implementation of the EU regulations (2008 and 2009-12 respectively), it is unlikely that such an effect is caused by this policy. Thus, it is possible that the market change has been caused by the actions of the Danish Energy Saving Trust to stimulate the CFL market. However, at present there is insufficient reported evidence to make a true causal link.

- **The European Union as a Single Market (including Switzerland and Denmark):** Data for the EU as a whole are not available prior to 2006, and the data presented from 2006 onward are derived and aggregated from a number of sources and so should be treated as highly illustrative. However, from the data available there is an *indication* that the EU regulations that came into force in 2010 are having market impact across the entire single market. Sales of incandescents have fallen from 66% of sales in 2008 to 52% of sales in 2010 (this 14% fall in the percentage of sales over 2 years is substantially larger than the 4% reduction over the preceding 2 years). These incandescent sales have been replaced by CFL and halogen sales, with CFL sales rising at approximately 1.5 times the rate of increasing halogen sales. This market change has improved the average efficacy of sales from 17.4 lm/W in 2009 to 18.5 lm/W in 2010. These efficacies still significantly lag behind those in the UK and

Australia (and potentially France – see below), but that is to be expected given the earlier *effective* adoption of regulations in these countries.

- **France:** The only comprehensive data on lamp sales in France are for 2007, and these data are based on significant assumption and manipulation, so the level of accuracy is unclear. However, based on these data, in 2007 the overall average efficacy of all lamp sales in France is estimated at 15.1 lm/W, ahead of both the UK and Austria. In 2007 incandescent lamp sales were 68% of all lamp sales, and halogens 15% (4% low voltage and 11% mains voltage). CFLs are the only product for which a time series of sales exists for the period 2006 to 2009 (and these data are from a more reliable source than other French data). Over this period, sales of CFLs double (CFL sales were 17% of market in 2007). From these data it is possible to speculate that the French market is acting in a way similar to that in the UK, i.e. the market is adopting more efficient lamps ahead of the EU schedule and in line with the accelerated French timetable. However, there is insufficient evidence to strongly support this speculation.

- **Korea:** Despite the very high starting point in 2006 (31.1 lm/W) average efficacy of sales in Korea has continued to rise and reached 45.7 lm/W in 2009 – still twice as good as the next best country (the UK, which is well advanced in its phase-out programme). Such an improvement is a combination of the rapid reduction in the proportion of incandescents sold by 2009 (the lowest of all reporting countries at 14%), but also the fact that sales of halogen lamps did not rise in this period (they remained stable at just 10% of the market[60]). Thus, consumers are moving almost exclusively from incandescent lamps to CFLs *not* halogens as is happening elsewhere[61].

  Because of the rapidly changing profile of sales it is reasonable to assume the ongoing revisions to Korean standards have had a major market impact. However, it is not clear how much of an influence these standards have had in excluding the lower efficacy, small wattage halogen lamps from the market, or whether this is simply consumer preference.

- **USA**: Refer to Section 3.2.4.

3.2.2 Halogen lamps: a breakdown

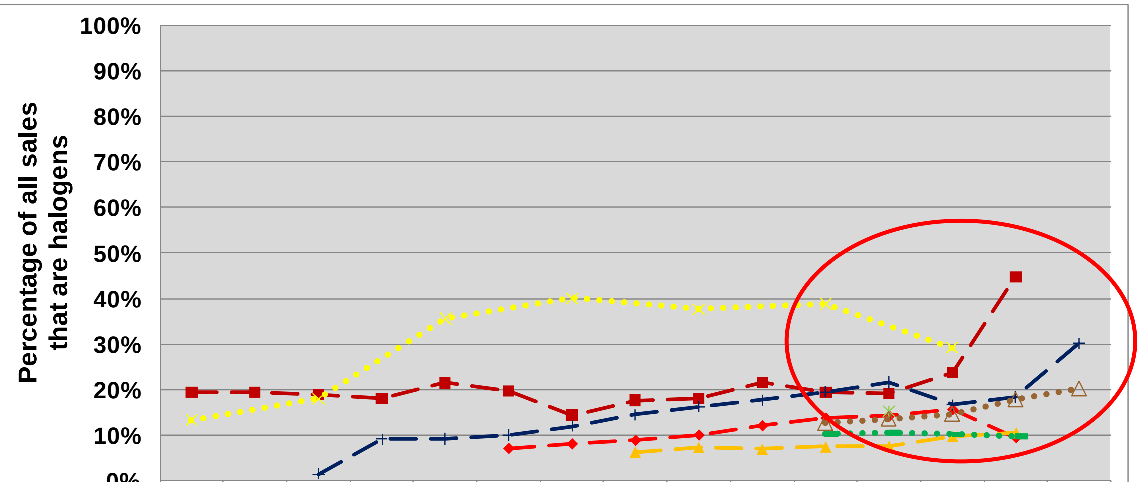
So far, the majority of the analysis has focused on the relative movements of incandescent and CFL sales, with only modest reference to halogen lamps. However, there is an important

[60] This is an estimate by the data supplier KEMCO as very little data for halogen sales currently are available in Korea. However, anecdotal evidence supports the view that use of halogen lamps within the stock has stayed relatively stable for a number of years.
[61] Note that until recently the preference for CFLs over halogens was *probably* due to cultural factors as most halogens would have been able to comply with local efficacy regulations. However, under the most recent Korean regulations, it is likely the majority of halogen lamps would be prohibited, particularly at the lower lumen levels.

recent trend developing in the sale of halogens, particularly in those countries where regulations to improve efficiency are apparently taking effect.

Figure 21 shows total sales of all types of halogen lamps in reporting countries. In almost all countries, halogen sales have been rising slightly over time (the exceptions are Denmark where there is some difficulty in identifying the exact size and breakdown of the halogen market, and the small fall in the percentage but not absolute numbers of sales of halogen lamps in Austria in 2009[62]). However, as highlighted in Figure 21, recently the sales of halogens in the UK and Australia have become erratic, with a sudden increase in sales in the most recent years; from 24% to 40% in Australia between 2008 and 2009, and from 17% to 30% for the UK between 2008 and 2010.

Figure 21. Percentage sales of ALL types of halogen lamps.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	19%	19%	19%	18%	21%	20%	14%	18%	18%	22%	19%	19%	24%	45%	
Austria						7%	8%	9%	10%	12%	14%	14%	16%	9%	
Canada								6%	7%	7%	7%	8%	10%	11%	
Denmark	13%		18%		36%		40%		38%		39%		29%		
France												15%			
Republic Of Korea											10%	10%	10%	10%	
United Kingdom			1%	9%	9%	10%	12%	14%	16%	18%	19%	22%	17%	18%	30%
EU											13%	14%	15%	18%	20%

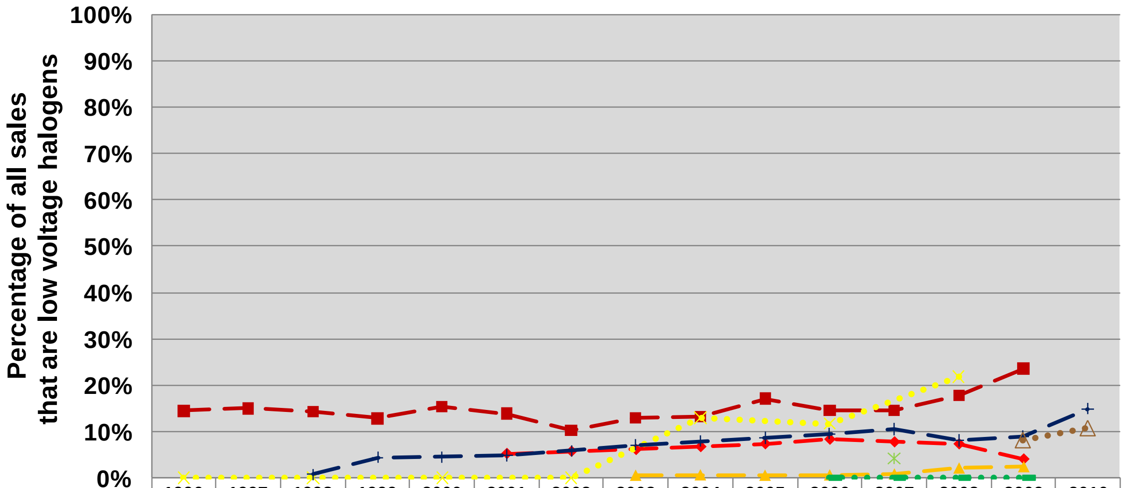
Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

Looking more deeply into this issue, the highlighted area in Figure 22 shows a continually rising trend in the sale of low voltage reflector lamps in most countries. Again there is the small fall in Austria in 2009 due to the unusual incandescent sales, and there are increasingly rapid rises in recent years in the UK and Australia, but these rises are nothing like as rapid as the sales of halogen lamps in general. Thus, given the absence of any policy

62 Caused by the spike in incandescent sales.

driver for so many countries over such an extended period, it appears to be very likely this is a gradual shift in consumer demand towards this kind of lighting[63].

Figure 22. Percentage of sales of low voltage halogen lamps.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	14%	15%	14%	13%	15%	14%	10%	13%	13%	17%	15%	15%	18%	24%	
Austria						5%	6%	6%	7%	7%	8%	8%	7%	4%	
Canada								1%	1%	1%	1%	1%	2%	2%	
Denmark	0%		0%		0%		0%		13%		12%		22%		
France												4%			
Republic Of Korea											0%	0%	0%	0%	
United Kingdom			1%	4%	4%	5%	6%	7%	8%	9%	10%	11%	8%	9%	15%
EU														8%	11%

Solid line = robust data *Dashed line = indicative data* *Dotted line = illustrative data*

Looking at the sales of mains halogen lamps in Figure 23, a similar gradual consumer trend towards adoption is shown, but in the case of the UK and Australia, there are sudden spikes in sales in the most recent years (6-21% in Australia[64] and 9-15% in the UK). This sudden spike accounts for the majority of the increase observed in all halogen lamp sales in these two countries and aligns directly with the introduction of regulation. Therefore a significant element of this spike is assumed to be consumers switching to 'look-alike' halogen lamps. For the limited EU data we have, it appears a similar trend is occurring here with significant increase in mains voltage halogen sales in 2009-2010, with no equivalent increase in sales of low voltage halogens.

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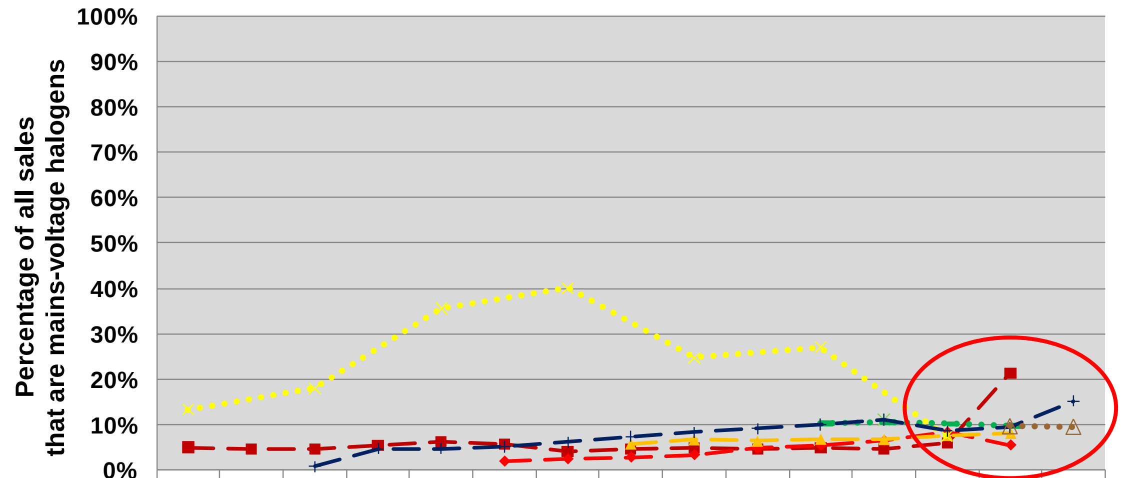
[63] It should be remembered that commercial sales of lamps are included in this analysis, so the trend may not simply be household usage, but may also include an increasing use of low voltage halogen reflector lamps in commercial environments.

[64] Subsequent provisional 2010 data from Australia implies single ended halogen sales have stabilised at 20% of all lamp sales.

This may be of concern to policy makers if they were anticipating regulation causing consumers to switch to CFLs as incandescents are withdrawn from the market. Clearly there is a segment of the market that is moving to halogen lamps in preference to CFLs, and the degree of this shift should be monitored very closely to ensure anticipated policy outcomes are not being distorted.

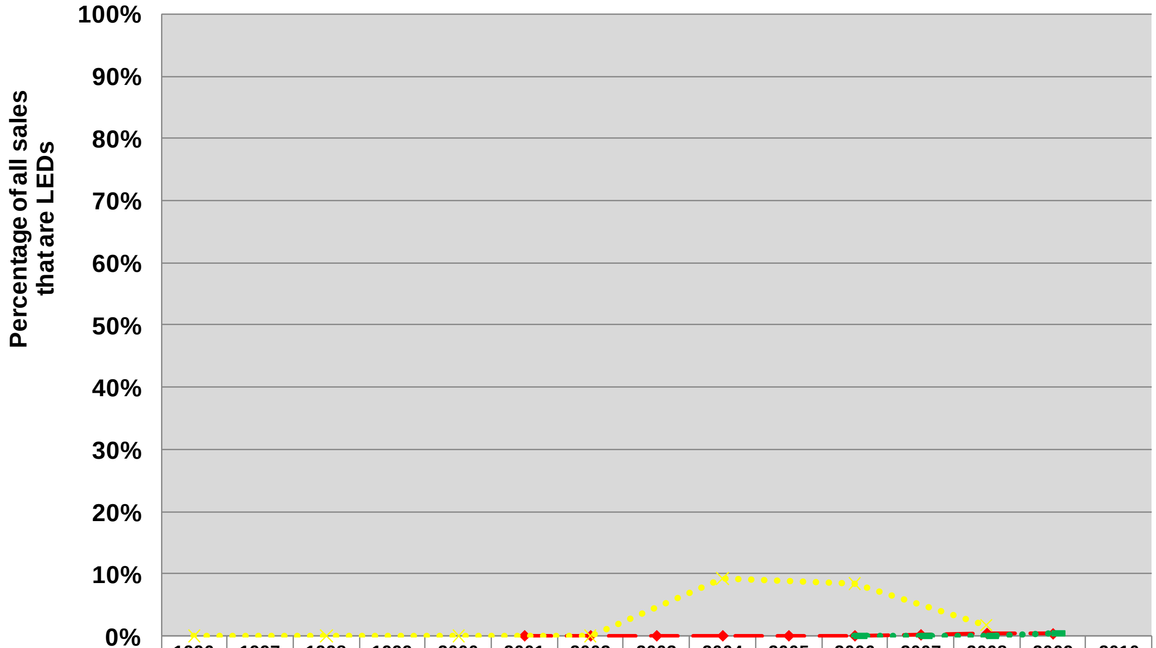
Figure 23. Sales of all mains voltage halogen lamps.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	5%	4%	5%	5%	6%	6%	4%	5%	5%	5%	5%	5%	6%	21%	
Austria						2%	2%	3%	3%	5%	5%	6%	8%	5%	
Canada								6%	7%	6%	7%	7%	8%	8%	
Denmark	13%		18%		36%		40%		25%		27%		7%		
France												11%			
Republic Of Korea											10%	10%	10%	10%	
United Kingdom			1%	5%	5%	5%	6%	7%	8%	9%	10%	11%	8%	9%	15%
EU														10%	10%

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 24. LEDs as a percentage of total lamp sales.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Austria						0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%	0.3%	
Denmark	0.0%		0.0%		0.0%		0.0%		9.3%		8.4%		1.7%		
Republic Of Korea											0.0%	0.0%	0.0%	0.3%	

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

3.2.3 Light Emitting Diodes (LEDs)

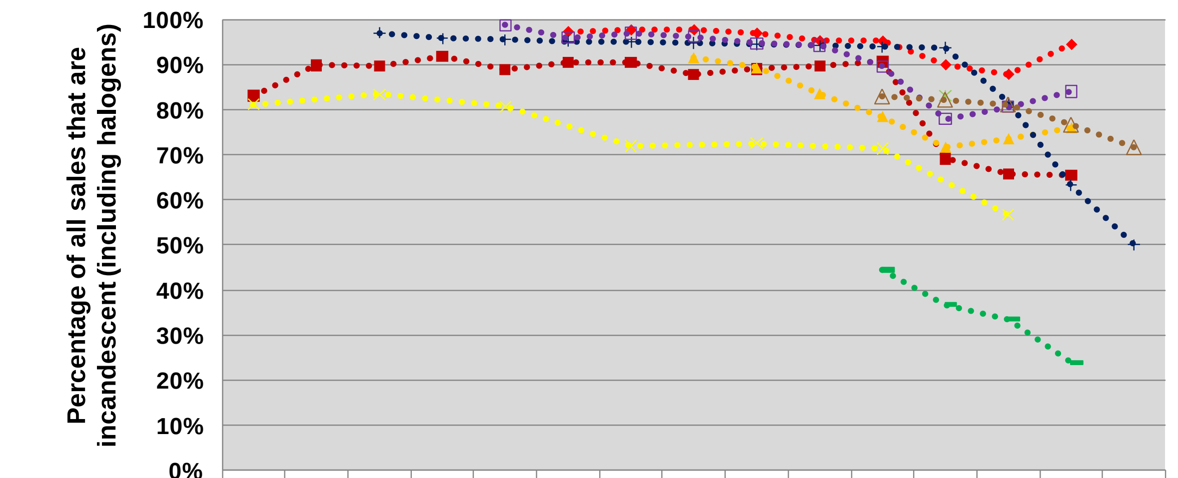
In recent years there has been very extensive publicity over the potential impact on the market of Light Emitting Diodes (LEDs) and similar products, e.g. organic LEDs (OLEDs). While there is little doubt the market entry of such lamps will cause significant changes to the type of lighting products purchased, and to their specific applications/use, it is worth spending just a moment to review Figure 24. At first sight there appears little value in including this Figure 24. However, it does reveal that, with the exception of Denmark, Australia and Korea, no country has reported the actual level of sales of LEDs for any year (and even Australian and Korean sales are very low). Clearly it is unlikely that sales of LEDs have been zero in *any* country. Therefore the zero sales reports are at least partly due to the very recent market entry of LEDs and the consequential lack of tools to monitor sales (this is certainly the case in the USA which has anecdotal reports of strong LED sales but no measure of the magnitude of these sales). Further, as the latest data on sales in some countries are for 2007, 2008 or 2009, LEDs had made less penetration in these years. However, from the anecdotal information that is available (and the fact that significant sales were not captured anywhere but Denmark), it must be recognised that total sales are still very limited *compared with the market overall*. Thus policy makers should be aware that, although the impact of LEDs *is likely to* be significant in the future, at present it is not clear to what degree, in which sectors, or how quickly this impact will occur.

3.2.4 *Comparisons with the USA*

As noted previously, due to difficulties in sourcing data on individual product types, the USA data group together all types of incandescent lamps (halogen and non-halogen lamps). This degree of grouping has a significant effect on the reliability of the outcomes due to the number and robustness of assumptions made when dealing with these data. Further, to benchmark other countries against the USA requires the data from other countries to be aggregated in a similar way to that within the USA dataset. This leads to a significant loss of clarity in interpretation of the outputs from benchmarking process. However, there are still insights that can be gained from such an analysis and these are presented in this section. The additional assumptions required to create these comparisons are detailed in Annex 3.

Figure 25 shows the sales of incandescent lamps (including halogen) as a percentage of sales of all lamps for all reporting countries. Figure 26 shows a similar graphic for the percentage of CFL sales and Figure 27 provides average efficacies of all lamps sold in each year.

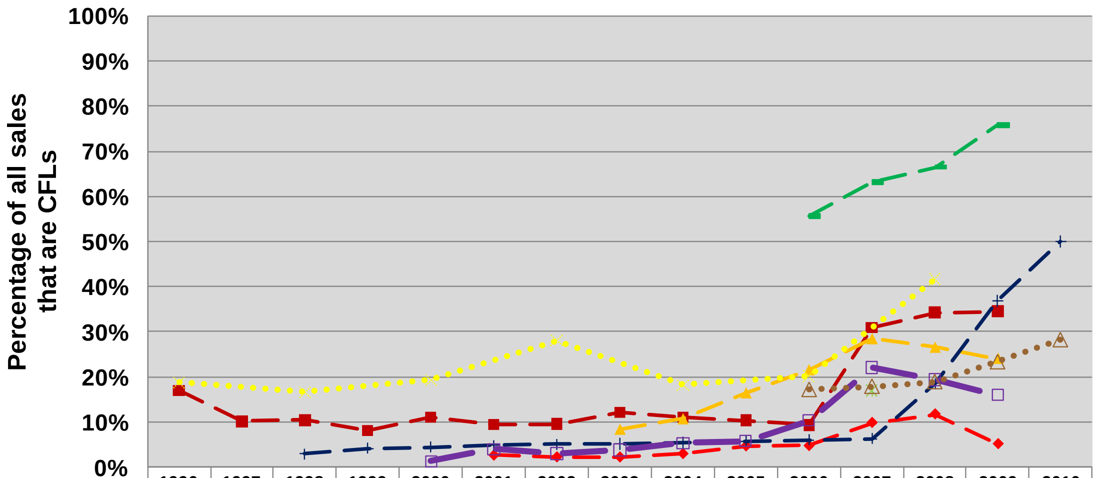
Figure 25. Percentage of all lamp sales that are incandescent (including halogens)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	83%	90%	90%	92%	89%	91%	90%	88%	89%	90%	91%	69%	66%	66%	
Austria						97%	98%	98%	97%	95%	95%	90%	88%	95%	
Canada								92%	89%	84%	78%	72%	73%	76%	
Denmark	81%		83%		81%		72%		73%		71%		57%		
France												83%			
Republic Of Korea											44%	37%	34%	24%	
United Kingdom			97%	96%	96%	95%	95%	95%	95%	94%	94%	94%	82%	63%	50%
USA					99%	96%	97%	96%	95%	94%	90%	78%	81%	84%	
EU											83%	82%	81%	77%	72%

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

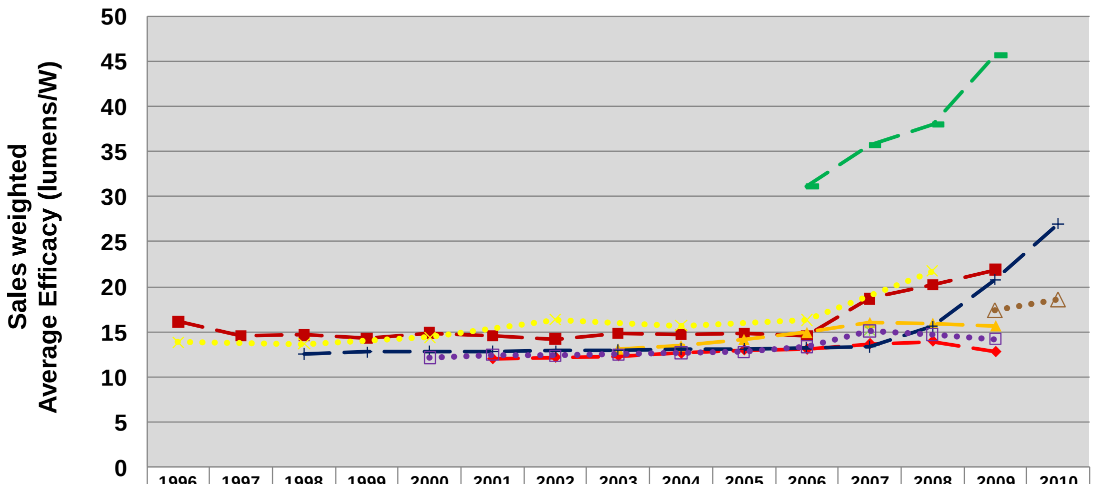
Figure 26. Percentage of all lamp sales that are CFL.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	17%	10%	10%	8%	11%	9%	10%	12%	11%	10%	9%	31%	34%	34%	
Austria						3%	2%	2%	3%	5%	5%	10%	12%	5%	
Canada								8%	11%	16%	22%	28%	27%	24%	
Denmark	19%		17%		19%		28%		18%		20%		42%		
France												17%			
Republic Of Korea											56%	63%	66%	76%	
United Kingdom			3%	4%	4%	5%	5%	5%	5%	6%	6%	6%	18%	37%	50%
USA					1%	4%	3%	4%	5%	6%	10%	22%	19%	16%	
EU											17%	18%	19%	23%	28%

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

Figure 27. Time series sales weighted average efficacy of lamp sales by country/region.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	16.1	14.6	14.6	14.2	14.9	14.5	14.2	14.8	14.6	14.9	14.6	18.7	20.3	21.9	
Austria						12.0	12.2	12.3	12.6	13.0	13.0	13.6	13.9	12.8	
Canada								13.1	13.4	14.1	14.9	16.0	15.9	15.7	
Denmark	13.8		13.6		14.4		16.3		15.7		16.3		21.7		
France												15.1			
Republic Of Korea											31.1	35.7	38.0	45.7	
United Kingdom			12.5	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.3	15.6	20.8	27.0
USA					12.1	12.5	12.4	12.5	12.7	12.7	13.3	15.1	14.7	14.2	
EU														17.4	18.6

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

In line with most countries, between 2000 and 2005 total incandescent sales in the USA remained relatively stable. However, during this period the US sales of incandescents were the highest of all countries with the exception of Austria (99% in 2000, 94% in 2005). During 2006 and 2007, the USA saw a sharp uptake of CFLs very much mirroring that in Canada, albeit starting slightly later and with a less strong peak in sales (starting at 6% in 2005, moving to 10% in 2006, and peaking at 22% in 2007). This made USA CFLs sales (as a percentage of all lamps sales) third only to Denmark and Canada among countries where no mandatory policy was in place or imminent, but still lagging behind Australia and significantly behind Korea. While no causal link can be clearly identified for this sudden boost in CFL sales, it seems likely to be a combination of direct and partner promotion of ENERGY STAR qualified CFLs (particularly related to the heavy subsidy programmes in many of the seaboard states/utilities).

However, again like Canada, sales of CFLs as a percentage of the market fell back to 16% by 2009. From the information available, there is no clear causal link for this fall in CFL sales, but it is consistent with the apparent reduction in utility funding of some CFL programmes, plus the potential saturation of the market for consumers willing to voluntarily adopt CFLs. Whatever the cause, by 2009, the USA has the lowest percentage of sales of CFLs for any reporting country other than Austria, and even Austria is only below the USA due to the unusual spike in non-halogen incandescent sales seen in 2009 (refer to Section 3.2.1).

Up until 2005, the high proportion of incandescent sales made the USA consistently amongst the worst performers in average efficacy of sales (with Austria and the UK), i.e. below 13 lm/W. However, the boost in CFL sales over the following years lifted the average efficacy of sales to 15.1 lm/W by 2007, thus moving the USA well above the UK and Austria, but still third from the bottom of all reporting countries (the next lowest being Canada at 16 lm/W). Over the following 2 years, the average efficacy of sales in the USA fell back to 14.2 lm/W by 2009 in line with the falling proportion of CFL sales. This later fall in efficacy coincided with the positive movements elsewhere in response to regulations and placed the efficacy of USA lamp sales a remarkable 50% lower than Australia, the UK and most likely Denmark, and an incredible 200% lower than average efficacy of lamp sales in Korea. Given current trends, this gap in efficiency of sales will continue to widen in the immediate future as there currently seems to be little response to the minimum efficiency regulations set for introduction in 2014.

It is worth noting that a number of commentators on the US market anticipate the efficacy of incandescent lamps (most likely some type of halogen lamp) will improve significantly prior to the introduction of regulations in 2014 and this will give consumers a wide choice of compliant incandescent products. No doubt this will improve the average efficacy of sales within the USA and lead to significant energy savings. However, given the fall in sales of CFLs over the last few years (as noted above *potentially* due to the saturation of willing purchasers), it is quite possible that when USA minimum efficiency regulations come into effect in 2014 there will be very little switching of lamp purchases to CFLs as seen in much of Europe, Korea and Australia. Hence the very significant increases in average efficacies seen in these markets may not be reproduced in the USA despite the higher efficacy requirements for all lamps compared with other countries/regions.

3.3 Key issues for policy makers

Policy makers may wish to note that there is clear and substantive evidence to suggest that regulatory frameworks to remove less efficient lamps from the market are proving successful in Australia, Korea and the UK, with the average efficacy of lamps sold rising by up to 50% in 3 years. This is despite the fact that the most recent policies are not 100% implemented in any of these countries.

At present there is no substantive evidence that such regulatory policies are affecting the market elsewhere (although they *may* be doing so in France and across the EU as a whole). However, this should **not** be interpreted as the policies being failures, but rather as a signal that the markets (or at least consumer buying patterns) are not being affected until the policies are very close to coming into effect.

Beyond these broad statements of overall impact, there are a number of observations that policy makers may wish to note when monitoring the impact of the policies as they come into effect or when developing or revising existing policies:

- The performance of Korea in managing its lighting market has been remarkable. Korea had a sales weighted efficacy of all lamp sales of 45% in 2009. This sales weighted efficacy is twice as good as any other country or region that has so far seen any policy impact, and around three times better than countries such as Austria, Canada and the USA where policy so far appears to have had little impact. It appears this strong performance is due to the extended period in which Korea has been regulating less efficient lamps (beginning in 2003), and the regular revisions of those requirements which are currently planned to culminate in a fourth generation of regulation which comes into force in 2014. These regulations will set the most stringent requirement on smaller lamps of all countries reported. It should further be noted that the 2014 requirement is already set even though the preceding regulations are phased for introduction over the 2009-2012 period. Hence the indication is that regular and well signposted regulatory revision of the lighting market is highly successful.

- There has been a strong consumer backlash against the impending removal of inefficient lighting in Austria resulting in a doubling of incandescent lamp sales in the year prior to regulations taking effect. It is not yet clear whether this is a single year event or an ongoing issue during the initial phased introduction of regulations. However, what is clear is such an effect is counter to the intention of policy makers and will slow the ultimate impact of the policy as replacement lamps will enter the installed stock at a later date.

Such a situation was avoided in the UK (it appears) primarily due to the voluntary agreement with major retailers to remove the most inefficient products from sale prior to mandatory regulation within the EU. This removed the opportunity for consumers to purchase and store less efficient products. It is less clear how Australia avoided a similar situation, but there is anecdotal evidence to suggest the close liaison between government, industry and major retailers, and a relatively rapid implementation schedule, resulted in changes in supply similar to those under the UK voluntary agreement.

Hence, policy makers should be aware that significant delays between the date of announcement and the date at which regulations come into force may result in a short to medium term market effect completely at odds with the intention of the policy action. Thus a balance needs to be struck between allowing time for the supply side of the market to respond (and to allay issues such as stranded investment), compared with the adverse consumer response that may result from a significant delay in policy implementation after announcement, resulting in the ultimate market impact being delayed well beyond the actual introduction of the policy. It is likely this balance may be very different from that for other regulated products such as appliances.[65] If delay is unavoidable, then policy makers should consider mitigation strategies similar to those employed in the UK and Australia.

- In countries where recent regulation is most advanced (Australia and the UK), there is clear evidence that elements of the market are migrating from traditional incandescent to halogen lamps. Sales of mains voltage halogen lamps jumped from 5% to 21% in Australia (2009) and 9% to 14% in the UK (2010), most likely caused by widespread migration to ‘look-alike’ halogen lamps. While a degree of movement in this direction was anticipated, the degree to which this shift is occurring may come as a surprise, with many expecting very high levels of movement to CFLs with little market adoption of halogens. There is some anecdotal evidence that such a migration to halogen lamps rather than CFLs may be particularly evident in the USA as regulatory control occurs in 2014. However, all policy makers should be aware of this potential shift in their markets and may wish to monitor development very closely to ensure anticipated policy outcomes are not being distorted.

- At present evidence suggests there is little actual penetration of LEDs into the domestic lamp sector. However, the majority of data available are for the period up to and including 2009 and thus may not capture the most recent trends in the market.

[65] Note that the impact here is different from that of larger regulated appliances. In general consumers will not ‘stockpile’ appliances for use when their existing products are to be replaced, so policy has the potential to impact as soon as it comes into force. However, for lighting, both the product volume and price are very low so consumers are in a position to stockpile significant quantities, hence having the potential to significantly delay the actual impact on electricity consumption.

- Beyond regulatory policy, there is strong evidence that voluntary labelling programmes and promotion/subsidy support had an impact on the Canadian, Danish and USA sales of CFLs. However, with the potential exception of Denmark, it appears the impact of these programmes (as measured by sales of CFLs) appears to peak relatively quickly over a 2-3 year timeframe and then tail off. From available information it is not possible to establish if this tail off is due to a gradual reduction in the intensity of the policy intervention, or whether the initial boost in sales rapidly meets the potential demand from those willing to make the switch to CFLs, with later sales falling sharply and potentially reflecting replacement of CFLs, rather than additional switching by other users.

Annex 1 Terminology used

The following lists some of the terminology used within this benchmarking document. It does not attempt to provide a full listing of all terminology, but rather to provide a summary of terminology most frequently used and/or terminology used in a context with a meaning that is less well known or different to its more common usage.

CFL(s)	Compact Fluorescent Lamp(s). Covered CFLs are also sometimes referred to as 'look-alike CFLs'.
Clear lamp	Lamp with a transparent, or near transparent covering.
Efficacy	The efficiency of lighting as defined by rated light output divided by rated power input (lumen/watt or lm/W).
Efficacy tables	A table of global average efficacies (for the local voltage) broken down by lamp types, wattage groups and year used in the calculation of all efficacies displayed in the output graphs (refer to Annex 2 Wattage buckets, standard efficacy tables, standard lifetimes and normalisation of lamps on differing voltages.
GLS	General lighting service lamps. Refer to incandescent.
Incandescent lamp(s)	For the majority of this document, 'incandescent lamps' refers to all types of tungsten lamps (both reflector and non-reflector) *not* encapsulated by a halogen filled capsule. Depending on region, such lamps are normally referred to as one or more of the following, incandescent, GLS, golf ball, fancy round, candle, etc. The exception to this statement is Section 3.2.4. In this section all types of lamps defined above plus those in a halogen capsule are referred to as incandescent lamps.
Instantaneous lighting output	The rated light output of a lamp or group of lamps (in lumens or lm).
LED(s)	Light Emitting Diode(s). LED is used within the document to denote lamps of all types similar to LEDs, e.g. including Organic Lighting Emitting Diodes (OLEDs).
Lifetime light output	Total light output of a lamp (or group of lamps) over its lifetime defined by rated light output of the lamp multiplied by the rated lamp lifetime. Expressed in lumen hours (lmh).

‘Look-alike’ lamp	Refers to mains voltage, single ended halogen lamps and CFLs.
Low voltage, single ended halogen lamp	Typically 12 V lamps of either reflector variety or capsule.
Lumen	The measure of ‘quantity of light’, normally denoted by lm.
Mains voltage, double ended halogen lamp	Halogen lamps with two ends, most typically used in domestic environments to meet high-illumination needs (e.g. security/outdoor applications).
Mains voltage, single ended halogen lamp	A halogen lamp operating on domestic supply voltage (110-120 V or 220-240 V), with a single ended connection/cap. In the *majority* of cases these are reflector lamps or lamps which can be used as replacements for GLS incandescent lamp (also known as ‘halogen look-alike’).
Sales of [*lamp type(s)*]	The total sales of a single defined lamp type, or defined group of lamp types, within a particular country in a particular year.
Sales of [*lamp type(s)*] as a percentage of all lamp sales	The sales of a particular lamp type or group of lamp types as a percentage of all lamp sales in a particular country in a particular year.

Annex 2 Wattage buckets, standard efficacy tables, standard lifetimes and normalisation of lamps on differing voltages

The aim of the 4E mapping and benchmarking of lighting was to create:

- A comparison of the stringency of the various 'phase-out' regulations being introduced by each participant (and potentially others);
- A comparison of changes in overall average efficiency of new products entering each market.

To perform such an analysis, it is necessary to know sales of the various lamp types within each market, the wattages and efficacies of these lamps, and the lamp lifetimes. Within the limited resources of the 4E mapping and benchmarking annex, gaining accurate reporting of data on each of these variables for all lamps would be impossible, even if such data were available. However, rather than a comparison of the performance of individual lamp types, the goal is to seek comparisons across the *entire* market, i.e. to compare the overall changes in lamp selection by type and size and the resulting impact on *market efficiency*. Therefore, it has been appropriate to establish 'standard' efficacies and lifetimes for various types and wattages of lamps. This is appropriate because the degree of variation in average efficacies and lifetimes between lamps of a specific voltage and wattage range within each individual country (and indeed between countries) is very small compared with the difference in efficacies and lifetimes between lamp types. Hence, a number of standard wattage 'buckets' have been created for each lamp type and, for a specific year, an average efficacy has been used for lamps of the same voltage within the same wattage bucket. Similarly, an average lifetime has been used for each lamp type across all markets. These assumptions have been agreed by a pool of lighting experts from three continents.

Details are given below on the standard wattage buckets used in the mapping and benchmarking process, and the associated assumptions and derivations of the standard average efficacies, standard lifetimes and conversions for differing voltages.

Wattage buckets and assumed average wattage per bucket

Globally, the majority of lamps are rated by wattage.[66] For specific lamp types, the majority of lamps sold are from a number of discrete wattages, e.g. in Europe, traditional GLS incandescent lamps have normally been sold at 25 W, 40 W, 60 W, 75 W and 100 W. These

[66] Recently there has been a move in many markets to require the labelling (and in some cases mandatory rating) of lamps by their lumen output. However, in the majority of markets, this change has been very recent and typically lamps will still display rated wattage as part of mandatory safety requirements. As the mapping and benchmarking exercise seeks time series data, which in some cases date back to 1996, the data collection and subsequent data analysis is based on rated lamp wattage.

discrete wattages vary between lamp types and between countries. Further, these discrete wattages account for the majority of, but not all, sales; some lamps are sold at intermediate wattages. However, it is possible to capture sales of all lamps by using these discrete wattages to create ‘wattage buckets’. Typically these buckets have the discrete wattages for a particular lamp type as their upper limit, with the lower limit set immediately above the preceding discrete wattage (using our European example above, the wattage range for incandescent lamps may be set at *x* ≥25 W; 25 W>*x* ≥40 W; 40 W>*x*≥60 W; etc). This has been the approach adopted by the mapping and benchmarking annex, with the discrete wattages agreed at the product definition stage.

The wattage buckets used to collect sales data and for subsequent analysis are shown in Figure 28.

Figure 28. Wattage buckets defined for data collection.

Lamp Type	Wattage Ranges									
Main Voltage Incadescents	0-25	26-40	41-60	61-75	76-100	>100				
Mains Voltage Halogens (single ended)	0-17	18-20	21-28	29-43	44-53	54-73	>73			
Mains Voltage Halogens (double ended)	0-100	101-150	151-200	201-250	>250					
Low Voltage (12V) Halogens	0-34	35-38	39-50	51-100	>100					
Mains Voltage Pin Based CFLs	0-3	4-5	6-7	8	9-11	12-13	14-15	16-20	21-25	>25
Mains Voltage Self-Ballasted CFLs	0-3	4-5	6-7	8	9-11	12-13	14-15	16-20	21-25	>25
Mains Voltage Linear Flourescent Tubes (T5)	0-28	29-50	>50							
Mains Voltage Linear Flourescent Tubes (T8)	0-24	25-27	28-31	>31						
Mains Voltage Linear Flourescent Tubes (T12)	0-33	34-40	>40							
Retrofit LED Lamps	0-1	1-2	2-4	4-8	8-11	12-14	15-20	>20		
Dedicated LED Lamps	0-1	1-2	2-4	4-8	8-11	12-14	15-20	>20		

The *average* wattages of all lamps sold within a bucket is assumed to be the top of the range (the discrete wattage), less 5% of the range.[67] This 5% reduction recognises that the majority of lamp sales will be at the discrete wattage, whilst taking into account the significantly lower wattage lamp sales of wattages across the remainder of the bucket range.

Lamp efficacies

Efficacies of 220-240 V lamps

To analyse the information received on lamps, it is necessary to know the efficacy of lamps (lumens/watt). For a specific wattage, these efficacies will vary between lamps within the same market, and potentially more so between markets. Further, given wattage buckets are being used, the efficacies of lamps at the lower end of the wattage range of the bucket will typically be lower than the efficacy of lamps at the higher wattage range of the bucket.[68] However, the efficacy variation between individual lamps and of lamps of the same voltage

[67] For example, for a wattage rage 40 W> *x* ≥60 W, the assumed *average* wattage of all lamp sales in that bucket will be 60 W – ((60-40) * 5%) = 59 W.
[68] Lamp of lower wattages are typically of lower efficacy than lamps of the same type with higher wattages.

within a bucket is far outweighed by the differences between lamp types. Hence it is reasonable to use an average efficacy for each wattage bucket.

For the year 2010, average efficacies of lamps in each wattage bucket (at 220-240 V) have been created based on a combination of actual test data of lamps purchased in Australia, China and Europe, and where test data is not available, by a review of manufacturer declared efficacies for a range of lamps in those buckets. The efficacies used in 2010 are shown in Figure 29.

Figure 29. Assumed 220-240 V lamp efficacies by lamp type and wattage bucket.

Main voltage incandescent (W)	0-25	26-40	41-60	61-75	76-100	>100			
2010 (efficacy)	*8.7*	*10.2*	*11.8*	*12.5*	*13.5*	*14.8*			
Mains voltage halogens (single ended) (W)	0-17	18-20	21-28	29-43	44-53	54-73	>73		
2010 (efficacy)	*11.5*	*11.9*	*12.0*	*13.5*	*15.0*	*17.3*	*18.5*		
Mains voltage halogens (double ended) (W)	0-100	101-150	151-200	201-250	>250				
2010 (efficacy)	*16.0*	*17.5*	*17.8*	*19.0*	*20.0*				
Low voltage (12 V) halogens (W)	0-34	35-38	39-50	51-100	>100				
2010 (efficacy)	*17.0*	*18.2*	*18.8*	*21.7*	*23.0*				
Mains voltage pin based CFLs (W)	0-3	4-5	6-7	8.0	9-11	12-13	14-15	16-20	21-25
2010 (efficacy)	*50.0*	*51.5*	*59.0*	*62.0*	*65.2*	*69.0*	*72.0*	*66.9*	*74.2*
Mains voltage self-ballasted CFLs (W)	0-3	4-5	6-7	8.0	9-11	12-13	14-15	16-20	21-25
2010 (efficacy)	*40.0*	*50.0*	*51.1*	*52.2*	*56.4*	*56.0*	*57.5*	*62.5*	*61.4*
Mains voltage linear fluorescent tubes (T5) (W)	0-28	29-50	>50						
2010 (efficacy)	*87.8*	*94.0*	*94.0*						
Mains voltage linear fluorescent tubes (T8) (W)	0-24	25-27	28-31	>31					
2010 (efficacy)	*67.2*	*73.0*	*79.1*	*84.4*					
Mains voltage linear fluorescent tubes (T12) (W)	0-33	34-40	>40						
2010 (efficacy)	*73.0*	*74.0*	*75.0*						
Retrofit LED lamps (W)	0-1	1-2	2-4	4-8	8-11	12-14	15-20	>20	
2010 (efficacy)	*48.0*	*49.6*	*51.2*	*54.4*	*56.0*	*57.6*	*60.0*	*64.0*	
Dedicated LED lamps (W)	0-1	1-2	2-4	4-8	8-11	12-14	15-20	>20	
2010 (efficacy)	*60.0*	*62.0*	*64.0*	*68.0*	*70.0*	*72.0*	*75.0*	*80.0*	

For almost all lamps, efficacy has been improving over time. This improvement varies significantly between lamps. For example, the improvement in LED efficacies has been rapid in recent years, while incandescent lamps have improved very slowly. This improvement in efficacy over time has been accounted for by assuming an average annual improvement in efficacy for each lamp type as detailed in Figure 30[69].

Figure 30. Assumed annual increase in lamp efficacies by lamp type.

Lamp type	Annual improvement in efficacy
Main voltage incandescent	0.1%
Mains voltage halogens (single ended)	0.3%
Mains voltage halogens (double ended)	0.3%
Low voltage (12V) halogens	0.3%
Mains voltage pin based CFLs	0.6%
Mains voltage self-ballasted CFLs	0.6%
Mains voltage linear fluorescent tubes (T5)	0.3%
Mains voltage linear fluorescent tubes (T8)	0.2%
Mains voltage linear fluorescent tubes (T12)	0.1%
Retrofit LED lamps	10.0%
Dedicated LED lamps	10.0%

Efficacies for each wattage bucket over time have then been calculated by the formula:

Efficacy in year n-1 = Efficacy in year n x [1/(1+annual improvement in efficacy)]

Thus the efficacies for all lamps in previous years can be deduced from the efficacies of lamps in 2010.

Efficacies of 110-120 V lamps

For lamps with an integral or external electromagnetic/electronic control unit (e.g. CFLs, LEDs fluorescent lamps with ballasts, etc), there is very little difference in efficacies between 220-240 V lamps and 110-120 V lamps. Therefore the efficacy tables for each wattage bucket calculated for 220-240 V lamps are also used for 110-120 V lamps.

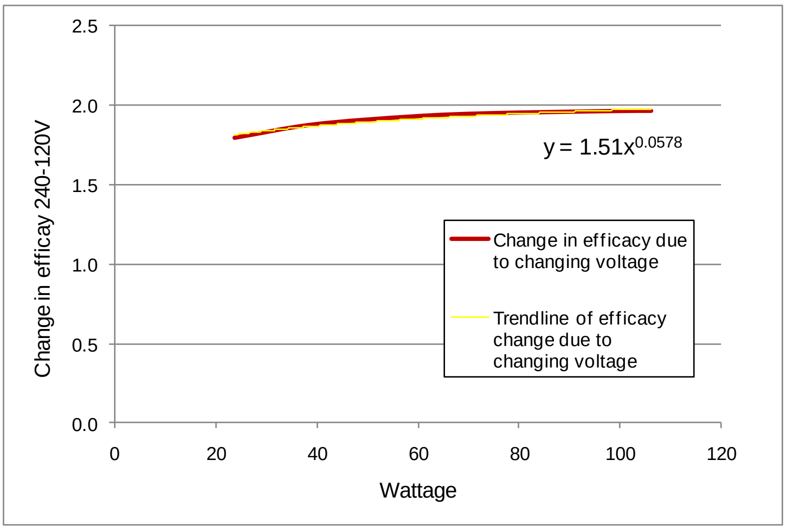
For lamps that use a filament to produce light (incandescent and halogen lamps) there is an inherent improvement in efficiency for lamps operating on lower voltages. Therefore, it is necessary to determine the efficacies to be used for filament lamps operating on 110-120 V. Three separate conversion methodologies created by experts[70] were identified for the conversion of 110-120 V *incandescent* lamps to their 220-240 V lumen equivalents. These conversions result in efficacy variations of between 1 and 3 lumens/watt over a range of lumen levels (typically the different methodologies result in efficacy differences reducing as lumen output increases, i.e. larger lamps have less variation). However, the derivation of these methodologies is not completely in the public domain and so not entirely transparent. Therefore, for the mapping and benchmarking work, a conversion has been developed based on an IEC standard (IEC 60064:2005).

[69] Note that annual improvements are assumed to be the same percentage over time.
[70] Two conversions methodologies have been created by Ecos Consulting in the USA, and one by Navigant Consulting in the UK.

IEC 60064:2005 provides minimum lumen values for given wattages at a range of voltages – thus these wattage and lumen values (and hence efficacies) can be considered comparable at each voltage. However, the table provides only a limited number of values based on minimum performance levels. To enable 120 V comparative efficacy values to be calculated for each 240 V wattage/efficacy combination used within the mapping and benchmarking analysis, manipulation of the data was required as follows:

The difference in efficacy values at various wattages shown in IEC 60064 of lamps for 120V and 240V was plotted (see Figure 31).

Figure 31. 110/120 V to 220/240 V filament lamp conversion factor.



The trend line[71] shown allows a function to be derived which in turn is used to define the change in efficacy between 220-240 V[72] and 110-220 V for each of the wattage buckets used in this analysis.

Note that IEC 60064 proves equivalents for *incandescent* lamps. However, no similar equivalents have been identified for halogen lamps. Further, no conversion methodologies for halogen lamps have been identified elsewhere. Therefore the same conversion methodology used for incandescent lamps outlined above has been used for halogen lamps. While it is likely that this approach is valid as both lamp types rely on heated filament as the light source, it is *possible* that the conversion will be less valid for halogen lamps.

[71] The trendline has the following equation: Delta efficacy = 1.15 * wattage$^{0.0578}$ or y = 1.15 * x$^{0.0578}$
[72] Note that IEC 60064 gives slightly different efficacy values for 110 and 120 V, and for 220 and 240 V. However, these variations are *very* small and thus the 120 V and 240 V values have been used to define the efficacies for the ranges 110-120 V and 220-240 V respectively.

Lamp lifetimes

The individual lifetimes of lamps vary considerably between models of a particular type. Similarly there are variations in average lifetimes of lamps between geographical regions and over time. However, for the mapping and benchmarking analysis, ‘standard lifetimes’ have been used for each lamp types in all markets for all years.[73] These standard lifetimes used are given in Figure 32.

Figure 32: Assumed average lamp lifetimes.

Lamp type	Assumed lifetime (hours)
Main voltage incandescents	1000
Mains voltage halogens (single ended)	1300
Mains voltage halogens (double ended)	1300
Low voltage (12V) halogens	1300
Mains voltage pin based CFLs	6000
Mains voltage self-ballasted CFLs	6000
Mains voltage linear fluorescent tubes (T5)	15000
Mains voltage linear fluorescent tubes (T8)	10000
Mains voltage linear fluorescent tubes (T12)	10000
Retrofit LED lamps	20000
Dedicated LED lamps	20000

[73] Note that ‘standard’ lamp lifetimes are based on an average of the lifetimes of lamps sold in 2010 as estimated by experts in the USA, Europe and Australia. Lamps in preceding years are *likely* to have shorter lifetimes and this has not been accounted for in the benchmarking.

Annex 3 Special assumptions for data processing from the USA

A number of specific assumptions are necessary in order to analyse the USA lamp sales data because sales of incandescent and halogen lamps have been consolidated and cannot be separated. While these assumptions are simple and are highly likely to result in the outcomes being somewhat inaccurate, they are considered reasonable for the purposes of this analysis. The assumptions made are:

1. 10% of reported incandescent sales are halogen lamps in all years.
2. The majority of these halogen sales are single-ended mains voltage halogens and the average efficacy and lifetime of single-ended mains voltage halogen lamps is assumed representative for that part of the incandescent sales data.[74]
3. The value for average efficacy and lifetime of incandescent sales in the USA data can be reasonably calculated as follows:

   *(Incandescent efficacy in year n * 0.9) + (Mains voltage halogen (single-ended) efficacy in year n * 0.1)*

   *(Incandescent lifetime * 0.9) + (Mains voltage halogen (single-ended) lifetime * 0.1)*

4. All USA CFL sales are of the self-ballasted type and have the typical efficacy and average lifetime for that lamp type.

To enable comparison with other countries where individual lamp breakdown is known, the data for other countries are calculated simply by consolidating the data provided into the same incandescent and CFL groupings in which the USA data was submitted. The percentages of sales by these two types is calculated as follows:

Incandescent market share = Sum incandescent sales / (sum incandescent sales + sum CFL sales)

CFL market share = Sum CFL sales / (sum incandescent sales + sum CFL sales)

The average efficacy calculation for non-USA datasets includes the very small contribution of LED lamps in the few datasets where this was included as this was considered a more accurate reflection of that market.

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[74] This approach is not applied to average wattage as the actual value for this is included in the data submitted.

Annex 4 Framework for grading mapping and benchmarking outputs

In order for the Mapping and Benchmarking Annex to provide transparency regarding the degree of 'reliability' that can be attributed to the results produced by the Annex, a framework has been developed that allows the *grading* of benchmarking outputs. This grading is based on a three part 'scale' of robust, indicative and illustrative. This scaling is applied to both the initial data input and any manipulations that are required to present the data in a consistent form in the country mappings, and to the subsequent manipulations of that data in order to make them comparable with datasets from other countries/regions during the benchmarking process. While expert opinion is used to formulate the specific grading allocated to individual data sets or outputs, this expert opinion is formed based on the following framework.

Grading of data/mapping outputs

Robust – where typically:

- The data are largely representative of the full market and
- The data include at least a significant element of individual product data and
- The data are from known and reliable sources and
- Test methodologies are known and reliable and
- Any data manipulations are based on solid evidence and should not unduly distort results.

Conclusions from such datasets are as reliable as reasonably possible within boundaries of the Annex operation.

Indicative - where typically:

- Datasets may not be fully representative of the markets (but do account for a majority, ideally a known and understood majority) and/or
- Any data manipulation used includes some assumptions or unavoidable approximations that could unintentionally reduce accuracy.

Accuracy is, however, judged such that meaningful but qualified conclusions could be drawn.

Illustrative – where typically:

- One or more significant parts of a data set is known to represent less than a majority of the full market or
- Test methodologies used to derive data are not known or
- Test methodologies used to derive data are known but could lead to significant differences in outcome or
- Data manipulations for the analysis contain an element of speculation or significant assumption or
- Conflicting and equally valid evidence is available.

Rather than being rejected completely, perhaps because the flaws in the data are at least consistent, such data could provide some insight into the market situation and so are worth reporting, but results must be treated with caution.

Grading of comparison between country outputs (benchmarking)

Robust – where typically:

- The data sources being compared are each largely 'robust' and
- No data manipulations for benchmarking were necessary; or if manipulations were used they were based upon solid evidence and should not distort results.

Conclusions from comparisons within and between such datasets are as reliable as reasonably possible within boundaries outlined above.

Indicative - where typically:

- Datasets being compared are themselves only 'indicative' and/or
- Any data manipulation used for benchmarking includes some assumptions or unavoidable approximations that could unintentionally reduce accuracy and/or
- For any other reason(s) subsets of the data may not be strictly comparable which leads to some distortion.

However, accuracy is such that meaningful but qualified conclusions could be drawn.

Illustrative – where typically:

- One or more significant parts of the datasets are themselves 'illustrative' and/or
- Data manipulations for the benchmarking process contain an element of speculation or significant assumption.

Rather than being rejected completely, perhaps because the flaws in the data are at least consistent, such data could provide insight into the market situation and so are worth reporting, but results must be treated with caution.

Annex 5 Justification for data grading

Country	Policy information	Mapping data	Benchmarked data	Efficacies	Justifications
Australia	Robust	• All data Indicative except LEDs and double ended halogen which are Illustrative	• All data Indicative except LEDs and double ended halogen which are Illustrative	• Indicative	• Projections supported by sales data with the exception of double ended halogens and LEDs
Austria	Robust	• All data Indicative	• All data Indicative	• Indicative	• Data based on sales
Canada	Robust	• All data Indicative	• All data Indicative	• Indicative	• Data based on sales
Denmark	Robust	• Incandescent data Indicative • Data on CFLs and all halogens Illustrative	• Incandescent data Indicative • Data on CFLs and all halogens Illustrative	• Illustrative	• Data based on highly detailed knowledge of limited number of dwellings. Deemed insufficient to gain full accurate picture of products with smaller sales (leading to some potentially erratic sales for products with lower penetrations)
France	Robust	• All data Illustrative except CFLs which are Indicative	• All data Illustrative except CFLs which are Indicative	• Illustrative	• Overall sales data scaled to align with more robust CFL sales data
Korea	Robust	• Majority of data Indicative • All halogen data illustrative	• Majority of data Indicative • All halogen data illustrative	• Indicative	• All data based on actual sales with the exception of halogen lamp sales which were estimated

Country	Policy information	Mapping data	Benchmarked data	Efficacies	Justifications
UK	Robust	• All data Indicative	• All data Indicative	• Indicative	• Data almost entirely modelled by outputs supported by a secondary, confidential data set
USA	Robust	• Incandescent data Illustrative • CFL data Indicative	• Incandescent data Illustrative • CFL data Indicative	• Illustrative	• Actual sales values thought to be accurate. However, assumptions necessary for processing incandescent data (eg average efficacy of halogen/incandescent mix) reduces reliability of this data
European Union	Robust	• All data Illustrative	• All data Illustrative	• Illustrative	• Mixed data sources providing widely differing values – all data to be considered highly illustrative
Taiwan	Robust	Not Applicable	Not Applicable	Not Applicable	Not Applicable