Energy Efficiency Series

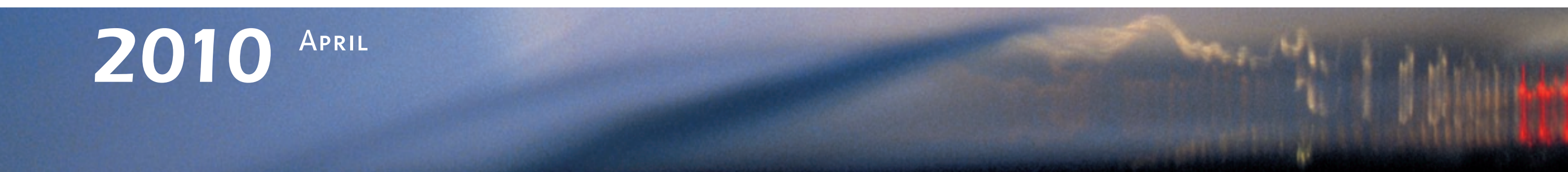
International Energy Agency

PHASE OUT OF INCANDESCENT LAMPS

Implications for international supply and demand for regulatory compliant lamps

INFORMATION PAPER

Paul Waide



2010 April

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its mandate is two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply and to advise member countries on sound energy policy.

The IEA carries out a comprehensive programme of energy co-operation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency aims to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency

International Energy Agency
9 rue de la Fédération
75739 Paris Cedex 15, France

International Energy Agency

PHASE OUT OF INCANDESCENT LAMPS

Implications for international supply and demand for regulatory compliant lamps

INFORMATION PAPER

Paul Waide

This paper was prepared for the Energy Efficiency Working Party in October 2009. It was drafted by the IEA Energy Efficiency and Environment Division (EED). This paper reflects the views of the IEA Secretariat and may not necessarily reflect the views of the individual IEA member countries. For further information on this document, please contact the Energy Efficiency and Environment Division at: eed@iea.org

2010 April

Table of contents

Acknowledgements

The author would like to acknowledge the support of colleagues at the IEA, particularly Jungwook Park, and to Ron Steenblik at the OECD Trade Directorate for their assistance in this project. Important technical and data contributions were made by numerous members of the lighting industry and especially by members of the ELC, CALI, NEMA, JELMA and ELCOMA. Special thanks are due to Philips, TCP and IKEA for their detailed input. Important additional information was supplied by NRCan, the European Commission, VITO, ECOS, NRDC and Steve Beletich.

Express thanks are due to the governments of Canada, the United Kingdom and the United States and to the European Lamp Companies Federation whose contributions made this work possible.

This work was funded by the governments of Canada, the United Kingdom, the United States and by the European Lamp Companies Federation.

Foreword

The majority of the work in this study was completed in 2008 prior to the European Union's (EU) announcement of its final regulations concerning the phase-out of incandescent lamps. An extra analysis was added in 2009 in the Afterword to reflect the impact of the newly adopted EU regulations.

KEY MESSAGES

1. Almost all OECD governments and many non-OECD governments are in the process of phasing-out standard incandescent lamps (GLS). Current global GLS sales are about 12.5 billion lamps per year but are beginning to decline in response to increased sales share for other lamp types.
2. Commercially viable, more efficient replacement technologies include: Compact Fluorescent Lamps (CFLi), advanced halogen lamps and light emitting diodes (LEDs). Of the present generation of these technologies, CFLi produce the greatest energy savings and are most readily available.
3. Sales of CFLi underwent a huge increase from 2005 to 2008 and, if lifespan is considered, have already supplanted GLS in terms of sales of future lamp socket occupancy *i.e.*, based on sales up to and including 2007 more sockets will be occupied by CFLi in the future than GLS as current GLS lamp stocks burn out. Global CFLi production output increased by 70% from 2005 to 2007 and reached approximately 3.5 billion lamps in 2007.
4. OECD demand for CFLi increased at an even faster rate than the international average in over this period to reach about 44% of the global market by volume; however, the average quality of lamps sold in the OECD is of a higher level than the international average and the OECD is estimated to account for over 70% of higher-quality CFLi lamp demand.
5. Under a reference case scenario, that assumes no GLS phase out policies are implemented, global demand for CFLi is set to reach five billion lamps per year by 2015 at a rate of growth of approximately 200 million lamps per year. This is half the rate of growth rates in recent years, which have been of the order of 422 million lamps per year. However, there are many uncertainties regarding the reference case forecast.
6. There are a range of potential CFLi demand outcomes in response to the pending phase-out regulations in the OECD depending on the stringency and rapidity of implementation of the regulations that are not currently finalised, most notably in Europe. Among those in which the main impacts of the pending regulations can be predicted with reasonable confidence (Australia, United States, Canada and Japan) demand for CFLi is expected to peak at 1 029 million lamps in 2014 and then hit a trough of 713 million in 2018 before rising afterward. This compares with demand in the same economies in 2007 of 590 million.
7. Depending on the stringency and rapidity of the regulations adopted in the EU, OECD demand for CFLi could rise to a peak of 1 728 million lamps in 2010 followed by a trough of 1 087 million in 2017, but less fluctuation is forecast if slower, less stringent regulations are adopted.
8. Decisions made in China will have an influence on global demand and supply of CFLi. If China introduces phase-out legislation, with a few years delay in implementation, it could effectively balance out fluctuations in OECD CFLi demand and greatly minimise the risk of stranded assets, *i.e.* production facilities with weak product demand, for CFLi producers. Demand profiles from the rest of the world will also have a significant impact on the total global demand profile.
9. Demand for other types of GLS replacement lamps are expected to increase from almost zero today to take up to 40% of the share of replacement sales depending on the nature of the regulations and the market. Solid state lighting such as LEDs are also expected to take a significant share of the future screw-base lamp market although this is not expected to be significant in terms of total illumination sales for another ten years; however, the rate of technology advance is very rapid in this domain and some industry sources are forecasting faster market penetration rates.

10. There appears to be less risk of a shortage of CFLi in general than of a shortage of CFLi of appropriate quality. Production is more constrained in this segment, which currently accounts for approximately 42% of global sales. Nonetheless many CFLi producers, especially those with headquarters in China, are confident they can produce sufficient quantities of high-quality CFLi if demand is forthcoming and their greater concern is with the risk of a sales drop following a sharp rise.

11. Continuing efforts to build on the present analysis and extend it to include regions that are not yet analysed will help to alleviate many of the remaining planning and decision-making bottlenecks. Regular international dialogue between regulators and industry will also help to minimise supply risks.

Executive summary

Since early 2007 almost all OECD and many non-OECD governments have announced policies aimed at phasing-out incandescent lighting within their jurisdictions. The intention of the regulations already adopted or under preparation is to encourage the usage of higher efficiency lamps and most notably CFLs in place of standard GLS lamps[1] and thereby eliminate a major source of energy waste. This study considers the implications of these policy developments in terms of demand for regulatory compliant lamps and the capacity and motivation of the lamp industry to produce efficient lighting products in sufficient volume to meet future demand. To assess these issues, it reviews the historic international screw-based lamp market, describes the status of international phase-out policies and presents projections of anticipated market responses to regulatory requirements to determine future demand for CFLs. A specifically adapted version of the global lighting energy simulation model developed for the publication, *Light's Labour's Lost: Policies for Energy Efficient Lighting*, is applied to perform this analysis using up-to-date detailed market data supplied by informed yet diverse sources.

A summary of the main findings is as follows:

- All IEA and EU countries excepting Norway have formally adopted policies to phase-out incandescent lamps. Many non-OECD markets are developing similar requirements or have already started phasing-out GLS lamps. The regulations vary in stringency, scope and schedule but all fall within the period up to 2020.
- New types of higher efficiency lamps have become available, which are broadening the choice of alternatives to GLS lamps.
- The diversity and performance of CFLi continue to improve and its suitability as a broad-based GLS alternative is less and less in doubt providing efforts are made to maintain the quality of the products available. Even higher-quality versions entered the market at the end of 2008, which amongst other benefits are understood to permit full dimming in all current dimmer circuits.
- An increasing array of solid state lighting products is becoming available but a variety of viability issues still need to be addressed before they can serve as high volume GLS replacement options.
- China dominates the global CFLi industry producing over 80% of global sales. China is also the largest single market for CFLi accounting for 34% of demand by volume, which is just less than the combined OECD demand.
- Global demand for CFLi has risen exponentially over the last decade and continues to rise at a dramatic pace. In 2007, for the first time, CFLi sales exceeded the sum of sales for all incandescent screw-based lamp sales (including GLS and halogen lamps) if viewed from the perspective of the product of lamp sales volumes and socket life expectancy. Sales growth was faster in the OECD than in other regions but grew dramatically everywhere.
- As a consequence the level of increase in demand for CFLi in direct response to the various international phase-out regulations will not be as great as once anticipated because demand has already risen and the replacement volume of future GLS replacement sales will be proportionately reduced.
- Nonetheless international demand for CFLi will be greatly increased, as to a lesser extent will demand for advanced halogen lamps, in response to the regulations. Various demand profiles

[1] On average a CFL uses a quarter of the energy of a GLS lamp for the equivalent light output and hence leads to very significant and cost effective energy savings. GLS and most CFLs have screw-base or bayonet-based fittings and hence are collectively called "screw-based lamps".

have been examined, which show that pending regulatory decisions in the EU and potentially China could have a large impact on the final magnitude and profile of demand. However, the risk of inducing shortages in lamp supply appears to be relatively modest as combined international demand profiles are only slightly peaked while the rate of the total growth in demand is most likely manageable by the international lamp industry if past precedent is a reliable basis for estimating the ability to add new production capacity. The risk is slightly enhanced if both the EU and China decide to opt for accelerated phase-out strategies but may be manageable nonetheless.

1. Introduction

Since early 2007, almost all OECD governments have adopted policies aimed at phasing-out incandescent lighting within their jurisdictions. All IEA member countries with the exception of Norway, have formally announced their intention to phase-out incandescent lighting and have either already issued regulations or are developing regulations that will put this into effect. The intention of the regulations already adopted or under consideration is to encourage the usage of higher efficiency lamps and most notably CFLs in place of standard GLS lamps.[2] The timing of the phase-out varies between OECD economies. In most cases, and for all the larger markets, a phased approach is being adopted where certain parts of the GLS market are prohibited from sale earlier than others. The start dates for when the phase-out regulations begin to enter into force vary from as early as the end of 2008 in the case of Australia to the beginning of 2012 for the United States, Canada and Korea. End dates for first tier requirements are between 2009 and 2014 for those which are already known. At the time the main body of the analysis was conducted the EU was still considering its phase-out schedules; however, the regulations that have eventually been adopted operate phased stages beginning in September 2009 and concluding in 2012. The OECD economies are not alone in this effort. Many non-OECD economies have announced phase-out policies and are also preparing regulations. Some, such as China, are undertaking formal assessments of the options and may well issue requirements in the coming few years. Others, such as Cuba, have already led the way and have phased out GLS lamps within their economies. In addition to the regulatory approaches being adopted, many softer options are being implemented or are under development, including large-scale market transformation programmes, utility energy efficiency schemes, retailer initiatives and fiscal/financial incentives. Many of these schemes are of sufficient scale to have a major impact on local GLS and CFLi markets.

Beyond the OECD, the United Nations (UN) Global Environmental Facility is establishing a global initiative to support the phase-out of incandescent lamps. This effort has an initial focus on China, which currently consumes almost three billion GLS lamps. China is also the dominant producer of CFLs for the global market, such that roughly 80% of all CFLs are manufactured there, including most of those sourced to OECD markets through the major lamp manufacturers: Philips, Osram Sylvania, and General Electric. The Chinese government and lighting industry association, CALI, have expressed interest in evaluating the pros and cons of an accelerated phase-out of GLS lamps in China as well as an evaluation of the probable cumulative impact of the international regulations on the global lamp market and in particular the demand for CFLs.

Within the international lamp market global GLS sales are showing signs of decline but are still around 12.5 billion lamps per year. Until recently OECD economies accounted for almost half of this figure but their share and total market volume is falling, as discussed in Section 4. Global demand for CFLi rose dramatically in 2007 to the point that for the first time in history, CFLi account for a greater proportion of lamp socket-life sales than GLS.

1.1. The GLS replacement-lamp demand and capacity issue

For each would be GLS lamp sale that is phased-out by the pending regulations consumers will be expecting markets to supply viable alternative lamps and regulators have a responsibility to ensure

[2] On average a CFL uses one-quarter of the energy of a GLS lamp for the equivalent light output and hence leads to very significant and cost effective energy savings. GLS and most CFLs have screw-base or bayonet-based fittings and hence are collectively called “screw-based lamps”.

that is the case. The principle purpose of this study is to assess the expected profile of demand for regulatory-compliant lamps to determine if there are likely to be risks of supply shortfalls. In principle, a risk of regulatory induced lamp shortages arises due to the following two possible factors:

a) Demand for regulatory-compliant lamps might increase too rapidly for the industry and supply chain to be able to satisfy it.
b) Additional demand might be short-lived and therefore industry may have little economic incentive to invest in the necessary production facilities required to meet the peak demand.

A third possibility is that demand for lamp sales volumes could be met but that the quality of the available lamps is insufficient to satisfy consumer expectations.

All of these risks are considered in this study but the main focus is to provide an assessment of probable lamp demand profiles, with a specific emphasis on CFLi, in order to help assess supply risks of type (a) or (b) above. The report is structured such that: Section 2 gives an overview of general "screw-base" lamp technologies and alternatives to GLS; Section 3 reviews the status and characteristics of phase-out policies internationally; Section 4 discusses recent lamp market trends; Section 5 reports projections of future regulatory-compliant lamp demand, Section 6 assesses the balance of lamp shortage risks associated with these demand profiles.

The reason why such risks may exist is now discussed.

The average lifespan of GLS lamps is 1 000 hours but for CFLs it depends on the market such that they have an average lifetime of roughly 4 500 hours in China, 6 000 hours in Europe and 8 000 hours in the United States.[3] The difference in lifetime of CFLs and incandescent lamps is important because each time a GLS lamp is replaced by a CFLi, the future lamp replacement cycle drops by a factor of from 4.5 to 8 depending on the CFLi lifespan. Were it possible for all incandescent lamps that fail to be replaced by CFLs, the annual screw-based (or bayonet) lamp market (ignoring current lamp sales already taken by CFLi) would fall from 12 to 13 billion lamps to roughly two billion lamps; however in the year the transition takes place there would be a demand for 12 to 13 billion CFLs. Such a rapid transition could not occur in practice because of the following:

a) There are insufficient CFLi production facilities globally to supply such a rapid acceleration in initial demand and it takes more time to bring new facilities on line.
b) Even were it possible to bring such facilities on line there would be no economic incentive for producers to pay to have them constructed unless the price they could charge for CFLi would rise to such a high level it would cover the costs of the facility within a single year before the sales demand dropped again.

   This extreme hypothetical example serves to illustrate the importance of the GLS phase-out rate and raises the question of what is the maximum speed of transition from GLS to CFLs that the global lamp market could support without there being a risk of lamp shortages? This is not an academic question. There is already a small illustration of the impact of regulatory settings on the supply of CFLs as it is reported that Cuba's ban on GLS lamps led to a temporary CFL supply shortfall in Latin America. This was apparently caused by a lack of awareness among the international supply chain of the new policy environment.[4]

The unprecedented rapidity of recent international policy developments with respect to the phase-out of incandescent lamps is of such a scale that it might pose a risk for the security of supply of

[3] Estimated average lifespan of new CFLi sales, as opposed to installed lamp stocks.
[4] Source: IEA discussions with Philips Lighting in July 2007.

CFLi in the international market. Depending on the timing and ambition of policy settings and the lamp production investment and disinvestment decisions taken in response to these, there may be a risk of compliant lamp shortages. In the event regulatory driven lamp shortages were to occur, public confidence in energy efficiency and greenhouse gas (GHG) abatement efforts in general could be seriously undermined and thus reasonable measures to minimise the risk of this occurrence must be taken. The analysis presented in the rest of this report is intended to help inform the assessment of such risk.

Although this study includes an analysis of all types of substitutes for incandescent lamps, it is mostly focused on the main substitute technology, CFLi.

2. Current incandescent lamps and substitute lamps: technologies, performance and related issues

2.1. Standard incandescent and halogen lamps

GLS and other standard incandescent lamps

The standard GLS lamp (so called “A shape”)has been the most commonly used light source since its simultaneous invention by Joseph Swan in the United Kingdom and Thomas Edison in the United States in 1879. GLS and other incandescent lamps can have either frosted (pearl) (GLS-F) or clear (GLS-C) coatings. Standard incandescent lamps are omni-directional, which means they distribute light to all parts of the surrounding space and thus are well suited to providing general illumination. Since their first entry onto the market they have been the dominant household electric light source in all OECD economies except Japan and Korea, where fluorescent lighting is prevalent; however, even prior to the current regulatory moves to phase them out they have been ceding market share to alternative technologies such as halogen lamps and compact fluorescent lamps, both of which are described below.

Incandescent lamps are very cheap to manufacture and purchase but are extremely energy inefficient (only 5% of input power is converted into visible light, the remainder is converted to waste heat) and hence are expensive to operate. A typical 60 W GLS lamp may only cost USD 0.3 to purchase but USD 6 to operate over its short 1 000 hour life span. Thus the operating costs are roughly 20 times the purchase price. The average efficacy (light emitted per input power) of GLS lamps varies with the light output (luminous flux) such that less bright lamps have lower efficacy levels than brighter lamps all else being equal. The same phenomenon applies to other light source technologies including halogen and fluorescent lamps. However, incandescent lamps have a much lower efficacy than fluorescent lamps and a slightly lower efficacy than most halogen lamps for a comparable amount of light output. A typical 60 W incandescent lamp will have an efficacy of 12 LPW if designed to operate on a 230 V mains power supply and 14 LPW if designed to operate on a 120 V mains power supply. The 60 W GLS lamp design for the 230 V system will typically emit about 720 lm whereas the 60 W GLS designed for the 120 V system will typically emit 850 lm. Thus although the most common GLS lamp type is 60 W in both 120 V and 230 V markets the light emitted and efficacy is about 15% less at 230 V.

Fittings and diversity of standard incandescent lamps

In most parts of the world GLS lamps are fitted with an Edison screw-base that is typically 26 to 27 mm in diameter. These are universally known as E27 bases but are also referred to as “medium screw” lamps in the United States. In some parts of the world *e.g.*, the United Kingdom, Australia, New Zealand, France and parts of Africa, many GLS lamps are fitted with bayonet bases (B22), but in all other respects are identical to “screw-base” incandescent lamps. For the rest of this paper the term “screw-based lamp” will be used as a generic expression to refer to lamps fitted with either screw or bayonet bases *i.e.*, as the generic term for lamps that have the most commonly used lamp socket type in the country concerned. Not all incandescent lamps use E27 bases; versions with narrower bases, such as E14, have also grown in popularity in most markets in order to accommodate smaller types of incandescent lamp designed to fit into smaller luminaries (lamp fixtures). These narrow-based incandescent lamps are often of a lower power and different shape. They encompass: "golf balls",[5] decorative lamps such as flame and candle shapes, but also "globes" that are spherically shaped with greater diameters than A-shape GLS. In all other respects the technologies are essentially the same as used in conventional GLS.

Household incandescent bulbs come in the following three main categories:

- General lighting: *e.g.*, 25 W-150 W power range with clear, frosted or pearl coatings and A-shape or candle shape.
- Decorative lighting: *e.g.*, silver cap, twisted, bent tip, carbon, flicker, coloured.
- Special lighting: *e.g.*, lamps for fridges, cooker hoods, sewing machines, ovens, etc.

In almost all parts of the world except the United States, the versions of GLS and decorative incandescent lamp described above define the vast majority of conventional incandescent lamp products available on the market. These lamps are invariably designed to last for 1 000 hours in countries using 220 V to 240 V mains power supplies. In the United States a broader variety of incandescent lamp technologies are in common use. In addition to the lamps described above there are also the following:

- Long-life incandescent lamps with life-spans of over 1 250 hours (up to 2 000 hours but lower than average efficacy levels).
- Short-life incandescent lamps with life spans of 750 hours.
- Rough service incandescent lamps.
- Vibration proof incandescent lamps.
- Modified spectrum lamps (also known as daylight lamps in other markets).
- Three-way lamps (designed to provide three different light output levels).

Incandescent reflector lamps

As the name implies reflector lamps use a reflector to give greater directional focus to the light emitted by the light source. GLS-R are standard GLS lamps with a modified bulb shape and a metallic reflective coating. Standard incandescent reflector lamps come in different shapes to give alternative directional properties to the light they emit. Some have ellipsoidal shapes and are known as ER lamps, others have parabolic shapes and are known as PAR lamps.

Halogen lamps

Halogen lamps are adapted tungsten filament lamps using an inert halogen filler gas around the filament. They were first developed in the late 1950s and come in two broad categories: mains voltage lamps (designed to operate at the local mains voltage) and low voltage lamps (designed to operate at 12 V DC. Halogen lamps come in a large variety of sockets and applications. Some mains voltage varieties use the same sockets as GLS but most use halogen specific sockets including socket types: G4, GY6.35, GU5.3, G9, GU10 and R7. The efficacy of conventional non-reflector mains voltage halogen lamps ranges from 14 LPW to 16 LPW at 60 W but is about 25% to 30% higher for equivalent low voltage lamps. Although the latter require the use of a transformer and the losses in

[5] Also known as "fancy rounds" in some markets.

these can substantially erode their efficacy benefit compared to mains voltage halogen lamps. Table 2.1 reports some typical examples at 220 V to40 V.

Table 2.1. Characteristics of typical standard halogen lamps (excluding reflector types)

Type	Power(W)	Luminous Flux (lm)	Efficacy (LPW)	Life (hours)
HL MV (60 W GLS replacement)	60	840	14	2 000
HL MV R7 socket	200	3 000	15	2 000
HL MV Capsule E27 base	75	1 050	14	2 000
HL LV capsule	50	950	19	3 000

As with other types of incandescent lamps the CRI of halogen lamps is 100 but the typical colour temperature is 2 900 K (just above standard GLS warm-white values).

Only the halogens using standard E27/26 or E14 bases could be substituted for GLS and other standard incandescent lamps without needing a simultaneous change in the socket. Nonetheless, halogen lamps with alternative socket types do compete for market share with GLS in the residential and to a lesser extent the professional lighting markets. Nor are like-for-like sources the only candidates for direct competition. Reflector lamps (such as MR-16 dichroic reflectors of either mains or low voltage type), capsule lamps (either single or double ended) and screw-base halogen lamps all compete for market share against GLS and other incandescent lamps in OECD households and are sensitive to consumer preferences regarding aesthetics, cost and convenience.

2.2. Higher-efficiency alternatives to incandescent lamps

CFLi

Compact fluorescent lamps with integrated ballasts (CFLi) come in a large variety of shapes and types. The diversity of types has increased considerably in recent years and the size has decreased enabling them to be used in a much greater set of luminaries than was previously the case.

CFLs are much more efficient than incandescent lamps and typically only use one-quarter of the energy for the same amount of light output. They also come in a broader range of colour temperatures ranging from the same CCT as incandescent lamps up to much higher values nearer to daylight. Life expectancy is anything from under 3 000 hours for very poor quality CFLi to beyond 15 000 hours for very high quality ones. As with other fluorescent light sources the CRI of CFLs is less than 100 (typically 80 to 85) but is high enough for most applications. Prices have also fallen substantially over the preceding decade such that high-quality CFLs now cost slightly over USD 1 at factory gate prices in China but can retail at much higher prices in the shops.

Although today's CFL technology is good several challenges still remain to be addressed:

- Most are not dimmable while the ones that are dimmable often do not dim in a fully satisfactory manner and can suffer performance degradation at reduced light levels.

- They contain small amounts of mercury, which has some health implications and public acceptance consequences.
- The light quality is not always satisfactory.
- Lumen maintenance issues: lamps get dim over time.
- Size still remains an issue for some applications.

CFL production and product quality vary considerably among producers and as a result there are significant differences in lamp quality. These are associated with differences in the quality of raw materials, the manufacturing process and the price the market is prepared to support to have superior-quality products. Less price sensitive, quality conscious markets as generally found in the OECD tend to demand higher quality, higher cost CFLi. More price constrained markets tend to receive poorer-quality products; however, there are quality issues which need to be addressed in all markets and not all OECD markets are insulated from poor-quality CFLi.

The "Super CFLi"

In order to address these remaining performance and acceptance issues manufacturers are working on the next generation of CFLi known as "Super" CFL (Yan 2008). The next generation of Super CFLs are focused on delivering enhancements to the two main parts of the CFL: the driver and the burner. While the existing CFLi market has transitioned from magnet ballasts to electronic ballasts, that offer distinctly superior performance characteristics, current electronic ballasts still work using analog technology. The Super CFL operates on a digital technology that delivers a CFL that features the following:

- Fully dimmable: smooth dimming down to 10% light output, with no colour shift.
- Full compatibility with all dimmers (both old and new dimming technologies).
- The capacity for the lamp to restart at any light level setting.
- High power factor.
- Better lumen maintenance via feedback adjustment on high frequency to lock lamp current.
- A 50% lower operating temperature.
- Higher efficacy (*i.e.*, a minimum of 70 LPW).
- Smaller size (by reducing the number and size of components).

It is reported that in addition the Super CFL will feature a special pre-coating on the tube that blocks the mercury from penetrating the glass and therefore reduces the amount of mercury that needs to be dosed. The special coating delivers a CFL that features:

- Lower levels of mercury: enough to operate the lamp without risking performance, degradation or the chance of mercury starvation *e.g.*, only 1.5 mg Hg required for up to 23WCFLi (equivalent to a 100 W incandescent).
- Longer life (minimum 10 000 hours).
- Better lumen maintenance (80% of initial lumens at the end of life).

It is reported that Super CFLi will initially carry a roughly USD 2 price premium but that this is likely to decline to USD 1 as the market matures.

Advanced halogen "energy saver" lamps

Since late 2006 advanced halogen GLS substitute lamps have begun to appear on the market that save between 30% and 50% of the energy for a GLS of comparable light output. Most of these lamps are designed to replace GLS lamps and have conventional mains voltage sockets (E27 or E14); however, high efficiency halogens have also been designed to replace less efficient halogens using low voltage sockets.

To achieve their elevated efficacy levels, these lamps use up to three separate techniques to improve their efficiency: (a) xenon filling gas, (b) infra-red coatings (c) step-down voltage via a built in transformer and ballast.

The use of xenon slows down the evaporation of the tungsten atoms from the filament, which extends the life time of the filament and allows it to operate at a higher temperature. In addition xenon has a lower thermal conductivity than argon and this reduces the heat losses from the filament and means that less external energy is required to keep the filament at operating temperature. The net result is a higher luminous efficacy than using argon.

Applying a special infra red coating (IRC) on the insides of the bulb causes more heat to be reflected back to the filament and results in less external energy input being required to keep the filament at operating temperature. This lowers the casing temperature of the bulb and increases the luminous efficacy of the lamp. It is believed that for this technology to be safely applied it is necessary to have a low voltage supply and hence a transformer for 220 V to 240 V lamps.

While, the addition of an integrated ballast with a mains to low voltage DC transformer adds production cost it also allows the lamps to be operated with an optimum power supply and thereby reduces the conversion losses in the same way that they are reduced for LV halogen lamps. The application of each of these measures adds costs compared to a conventional incandescent or halogen lamp type and hence will result in a higher final lamp price. The use of xenon alone will increase the lamp efficacy by roughly 30% but the 50% efficacy gains can only be achieved at present by the addition of the IRC and integrated transformer.

Comparison of Halogen Energy Savers and CFLi as GLS replacement lamps

In general advanced energy saver halogen lamps offer the following advantages compared to CFLi:

- Brilliant (sparkling) light with natural light colour and clear bulb.
- Perfect CRI.
- Fully dimmable.
- No mercury.
- Even more compact and hence slightly more versatile for luminaire design.

The disadvantages are:

- Lower energy and CO_2 savings (*i.e.*, 30% to 50% over GLS compared to over 80% for CFLi).
- Less economic over the lamp lifetime.
- Shorter lifetimes (up to 5 000 hours compared to up to over 10 000 hours).
- Newer technology with lower production volumes worldwide.

Cost and quantity

While the prices of conventional halogen and CFLi are well known, there is still some uncertainty about the market prices to be anticipated for advanced halogen lamps. Good-quality CFLi can cost as little as USD 3 to USD 4 in OECD markets although they tend to be appreciably higher in the EU where anti-dumping requirements impose extra duties on most Chinese CFLi brands.

The new xenon halogen mains voltage GLS substitute lamps, which use a halogen G9 burner but do not include IR coatings or ballasts, have been retailing for as little as EUR 1.5 in Europe (as compared to EUR 0.5 for GLS). Their cost is anticipated to fall to about EUR 1 by 2011. In Australia the same lamps were retailing for AUD 2.99 (USD 2.70).

In the United States, the cost of comparable lamps has been reported as around USD 5.0 but this would be expected to decline as sales volumes increase and does include IR coatings.

In Europe, xenon halogen lamps are being produced, which are direct substitutes for 40 W, 60 W, 75 W and 100 W GLS, 25 W and 40 W reflectors and 25 W and 40 W candle shapes. These lamps achieve about a 30% efficacy increase compared to comparable GLS but fall short of the highest levels achievable by also using an IRC and integrated low voltage ballast. For lamps incorporating this technology the production costs are much higher and the initial retail price is thought to be between EUR 9 and EUR 10. This would be set to decline were higher production volumes to be maintained but is always likely to be significantly higher than for simple xenon halogen lamps. Two models are currently available on the European market.

From these comparisons it appears that simple xenon halogen lamps may be expected to retail for prices similar to or even slightly below those for CFLi (depending on the market), while low voltage IRC xenon halogens will be expected to be more expensive than CFLi in 220 V to 240 V markets and even retail at a higher cost than future Super CFLi. One reason why it is thought such lamps may always be more expensive is that it is believed the transformer has to be of a high quality to survive the higher temperatures found in halogens compared with CFLi.

It is possible to retrofit GLS production facilities to produce xenon HL lamps but the manufacturing equipment is sufficiently expensive that it is likely to take at least five years of sales to make a return on the investment even at relatively high production volumes *e.g.*, 50 to 100 million lamps per year. Therefore the viability of the investment will be sensitive to the production period and volume of lamps that are to be produced by the facility. This in turn will be sensitive to the stringency and schedule of phase-out regulations that are being adopted.

In the case of CFLi the production volumes are already very high, but as will be seen in Section 5 are set to rise much further.

Solid state lighting[6]

Solid state lighting is making substantial progress and has experienced rapid gains in niches of the illumination market. The global LED market was worth about USD 4.2 billion in 2006 within which the lighting segment attained USD 205 million and was growing at approximately 37% per year; the most rapid of any high brightness LED application. Industry experts anticipate the LED illumination

[6] The information in this section is taken from the summary of the workshop "Status, Prospects and Strategies for LEDs in General Lighting" staged by the European Commission's Joint Research Centre (JRC) in Ispra, Italy on May 3-4, 2007, *http://re.jrc.ec.europa.eu/energyefficiency/html/Workshop_LED_34052007.htm*

market will reach about USD 1 billion in 2011. The majority of lighting applications use coloured (RGB) LEDs today, but white LED sales are expected to account for more than 60% of the total market by 2011.

Efficacy improvements

The energy performance of LEDs is continuing to improve dramatically and has approached 100 LPW in the production of white LEDs; however, these values are for cold white light sources (the warmer the light the lower the efficacy due to Stokes shift losses in the phosphors required) and is for low light levels *i.e.*, for about 350 mA, which draws about 1 W input power. Higher power LEDs are less efficient. Furthermore, these performance levels are recorded under optimal operating conditions; however, in real world situations the performance declines due to higher operating temperatures and other factors. Despite this the performance of power LEDs continues to improve rapidly and further improvement is expected. Efficacies of 100 LPW are already available and values of about 150 LPW are expected in the near future, but at present this has only been reached in laboratory conditions at low power levels. As efficacy increases, thermal management, one of the major problems with LEDs, is simplified and system costs can be reduced. This, more than the ultimate energy efficiency device, is a key reason why efficacy levels will need to continue to increase if LEDs are to capture a large part of the general illumination market. The theoretical efficacy limits of LEDs are over 200 LPW, but this is not taking into account balance of system losses.

Although LED efficacy is important, the optical (fixture) and electrical (driver) efficacy also have a large influence on overall system efficiency as losses in these areas lower the device-level efficacy below that of the LED itself. Optics with efficiency levels in the range of 80% have been achieved as have efficiencies of higher than 85% for both AC/DC and LED driver stages. For LED drivers, closed-loop feedback is also available to keep the performance stable over time. This will enable the LEDs to change from a basic light source to smart light processor.

Among the various examples of LED light sources on the market for the residential sector, an illustration of the best currently available technology is a warm-white (2 700 or 3 500 K) down-light providing 650 lm (equivalent to a 60 W GLS lamp) at 11 W wall-plug power, 60 LPW efficacy (wall-plug), with a colour rendering index of 92.

Organic Light Emitting Diodes (OLEDs) are another promising technology that ultimately could produce devices that are significantly less expensive than LEDs; however, OLEDs are some way behind LEDs in performance improvements but have already reached efficacies of 32 LPW to 64 LPW at 1 000 cd/m^2.

Areas for improvement

There are many areas where LEDs need to improve if they are to become commercially viable general illumination sources. For example, difficulties in producing batches of LEDs with matched colour loci and temperature requires extensive testing and binning (colour sorting) of LEDs and adds cost to the final products. LED producers are currently working to address key areas for future improvement, namely white colour uniformity, CCT and CRI.

There are multiple improvement challenges in the power chain of high brightness LEDs from “electricity in” to “light out”. The overall performance of the power chain is influenced by many parameters, and optimisation is necessary to limit colour shift over temperature and lifetime and efficacy decay with higher driving current.

An important limitation on the development of a mature LEDs illumination market is the need to develop and adopt standardised measurement and reporting procedures. Test methods and standards to measure LED performance and safety are currently under development but in the meantime performance claims are not verified and there is a large difference in the quality of products on the market. Many have low light levels and extremely cold colour temperatures (*i.e.*, bluish coloured light).

Of all the factors requiring improvement, cost is the main barrier to the wide-spread adoption of LEDs for illumination. The initial cost per 1 000 lumens of white LED light is currently two to fifty times higher than for conventional light sources (including the more expensive light sources such as T5 fluorescent). At the cheaper end of the scale the lighting performance and hence consumer acceptability of current LED lighting devices declines such that there is a significant trade-off between price and acceptable lighting characteristics.

Some advantages of LEDs

Despite the limitations of LEDs they also offer many considerable advantages including:

- The potential for highly compact lighting fixture dimensions.
- The ability to fit into conventional light fixtures.
- The potential for dimming without change in colour temperature.
- Adjustable light colour with use of multi-coloured LEDs, enabling dynamic colour control and high colour saturation.
- A large range of colour temperatures.
- Long operating life (at least two to three times longer than a CFLi) and high durability.
- Reduced maintenance costs.
- High luminous efficiency.
- Absence of IR and UV light (depending on the LED type).
- Increased safety due to their very low input power.
- Reduced heat levels (no risk of burns).
- Cold start-up (down to -40°C) and higher efficacy at cold temperatures.
- Precise directional emission without accessories or refractors.
- The capacity to use efficient optics made of polymers.

Prospects of SSL for general illumination and as a GLS substitute

There appears to be general agreement in the lighting industry that LEDs will become an important technology to reduce lighting consumption in buildings and other applications, by offering better light quality than fluorescent lamps, and reaching the same level of efficacy (or even going beyond it). OLED technology, still in the R&D phase, is expected to bring additional cost savings and further enlarge the application of solid state lighting.

At present LEDs are still a niche lighting technology, though they do offer many advantages in some applications. One of the most successful niche applications is for portable lighting, such as torches (*i.e.*, flashlights), where LEDs offer superior performance. Another emerging niche application is the use of LEDs with photovoltaics. This is currently becoming common place for garden lighting in developed countries, but also offers a cost-effective solution for lighting in off-grid situations in developing countries. LEDs not only dramatically improve the quality of lighting, but also improve the indoor air quality compared to fuel based lighting. Furthermore, the cost of solar-PV LED lighting is much less than for fuel-based lamps using kerosene (paraffin).

In the residential lighting sector, LEDs are still a new light application, sold mainly as a fashionable and expensive light source. However, LEDs are already making a breakthrough in the retail sector (fashion and jewellery shops), and frozen food cabinets in supermarkets. LEDs also offer the opportunity for creative design, particularly for architectural lighting, and for the use of coloured light. While the lumen cost of LEDs dropped by about 30% in 2007 and is expected to continue to decline, current costs for acceptable products are still too high for the general indoor lighting market. Long lifetime, energy savings and low maintenance costs can help to compensate the high initial costs of LEDs and thus the total cost of ownership (TCO) may be becoming comparable to other light sources. However, the screw-base lamp market is the most first-cost conscious illumination sector. It has taken 20 years for CFLi to capture a large market share in the screw-base lamp market despite offering fantastic rates of return on investment compared to GLS (IRRs of over 180% when substituting for GLS). In the case of LEDs the payback period may need to be amortised over 50 000 hours of operation, which is more than 50 years of GLS use in OECD households, so it is probable that LEDs will continue to make greatest headway in the professional lighting market in the near-term with the exception of decorative luminaries (*e.g.*, ones that offer aesthetic appeal but are not designed to provide the bulk of general illumination) in the residential market.

Nonetheless LEDs have begun to make headway in the general illumination market for households *e.g.*, it has been reported that they accounted for over 10% of sales value in the French household lighting market in 2007; however, there are reasons to believe that this will not be sustained and that it will take many years for substantial inroads to be made into the domestic lighting and GLS replacement markets. The primary problem is that initial costs are much higher than consumers are likely to find acceptable for lamps that provide main illumination and are likely to stay so for many years. Current LED household light sources provide low, mostly cold, light levels and have problems in light matching and other quality and performance related factors that may well induce a public reaction against the technology much as bedevilled the CFL market up to 2000. Opinion appears to be divided on how rapidly LED illumination devices would be expected to overcome the array of technical, standardisation, cost and market problems they confront, but there is every reason to believe they will form the backbone of general illumination systems at some point in the future.

For the analysis conducted in this study we aim to err on the side of caution and assume a relatively pessimistic pace of development compared to other forecasts; however, this is because there are still too many unknowns to be able to form a dependable picture and therefore it is better not to place too much reliance on an uncertain technology.

3. The status of international regulatory developments to phase out incandescent lighting

Since the end of 2006 at least 37 nations have adopted policies to phase-out incandescent lamps and many more are considering their adoption. A history of the sequence of events associated with these policy developments is presented in Waide (2007) and in CLASP (2008).

The countries already committed to the phase-out of incandescent lamps comprise almost all the economies of the OECD and account for more than one-third of global incandescent lamp demand. Other major economies, most notably China, are also considering the adoption of policies to phase-out incandescent lamps and are likely to put in place measures in the next few years. The regulatory compliant lamp demand analysis presented in Section 4 is mostly determined from an analysis of the impact of the currently expressed policies, although the impact of hypothetical future policy measures is considered for the key market of China.

3.1. Cuba

Cuba has the distinction of being the first country to phase-out incandescent lamps. The Cuban authorities were moved to phase-out incandescent lamps when they realised the considerable benefits that higher efficacy CFLs offer compared to GLS; namely, Factor 4 power and energy savings, an average pay back period of two months, five times greater lifespan and reductions in national power demand of 25 MW for each million lamps replaced. Cuba adopted a dual approach wherein regulations banning the import and sale of incandescent lamps were adopted and enacted, and in addition a country-wide programme of in-situ replacement was implemented in 2006 and 2007. Under this programme social workers visited households, replaced the existing incandescent lamps with CFLi free of charge and then destroyed the replaced incandescent lamps to ensure they were removed from service. Cuban authorities report that they have since introduced this programmatic approach to 16 other countries and that as of June 2008 some 116 million incandescent lamps had been replaced in Cuba and beyond. It is further reported that these measures are achieving the following (Gonzalez 2008):

- Saving 4.5 million tons of fuel per year.
- Saving over 8 Mt-CO_2 emissions per year.
- Reduced the peak electricity demand by 3 980 MW (*i.e.*, by 34 MW per million lamps replaced).

The Cuban programme and its associated efforts in neighbouring countries has undoubtedly been of a major scale and has had a significant impact on the demand for CFLi in Latin America. Lamp manufacturers have reported being taken by surprise by the sudden surge in demand for CFLi in the region and this is reported to have led to a temporary shortage in CFLi beyond regional boundaries. CFLi import data for Latin America confirm the scale of the increase in demand.

3.2. Australia and New Zealand

After Cuba, Australia is the second country to have adopted a formal policy to phase-out incandescent lamps, subsequent to a ministerial announcement in February 2007. Since that time the Australian authorities worked to finalise regulations stipulating precisely how the policy was to be implemented. This required resolution of a number of technical and market issues. New Zealand initially joined Australia in this effort and the two countries then agreed to operate a mostly harmonised system. Since that time New Zealand changed its policy and is not believed to be about to regulate the efficiency levels of household lamps. The details of the Australian policy are now described.

Approximate GLS market volume in 2007:	~35 million units
Approximate CFLi market volume in 2007:	~41 million units
Mains power supply voltage	230/240

GLS figures include GLS-R and decorative incandescent lamps.
Note: GLS sales had been approximately 72 million in 2006.

Beginning in November 2008, in phased steps through to 2012, general service lamps imported and sold in Australia are required to surpass the luminous flux levels specified by the following formula:

Initial Luminous Flux (lumens) = 2.80×ln (Initial Efficacy (lumens/watt)) – 4.00.

Separate requirements have also been prepared for CFLi and include quality requirements addressing:

- Start time
- Lifetime
- Lumen maintenance
- Power factor
- Colour (xy, CCT and CRI)
- Mercury level
- EMC

These requirements are based on pre-existing ELI and UK Energy Saving Trust specifications for good-quality CFLs.

The time table for this first tier of minimum energy performance standards (MEPS) is shown in Table 3.1.

With few exceptions the requirements are not technology specific *i.e.*, they will apply to all types of lighting. The affected lamps include the following:

- Tungsten Filament Incandescent lamps (including General Lighting Service [GLS]).
- Tungsten Halogen: low voltage and mains voltage.
- Reflector and non-reflector lamps.
- Candle lamps, fancy round lamps and other decorative lamps.

As in other economies the development of requirements for reflector lamps has needed new test standards to be developed. Separate minimum mandatory performance requirements have also been developed for CFLs to ensure that they will meet consumer expectations.

Table 3.1. Schedule of Tier 1 lamp MEPS in Australia

Enforcement date for import restriction	Enforcement date for sales restriction	Lamp types required to meet MEPS
Nov-08	Nov-09	GLS ELV halogen non-reflector CFLs
Nov-09	Nov-10	>40 W candle, fancy round, decorative (G9 base excluded) ELV halogen reflector
Nov-10	Nov-11	CFL, reflector
Nov-11	Nov-12	Mains voltage reflector lamps Inc. halogen (PAR, ER, R, etc.) >25W candle, fancy round, decorative lamps
To be determined	To be determined	Pilot lamps 25 W and below

Source: Slade (2008).

Figure 3.1. Efficacy vs luminous flux requirements to be applied in Australia and the performance of various common light sources

Source: Beletich (2008).

In addition to meeting these efficacy requirements lamps will also be required to have:

- Lifetime (>= 2000 h).
- Lumen maintenance of >=80%, measured at 75% of rated life.

Anticipated impacts on the future lamp market

Although the efficacy requirements as specified by the curve fall a long way short of requiring the most efficient types of screw-based lamps (*e.g.*, CFLi) they will have the effect of phasing-out all conventional GLS and affected conventional mains voltage halogen lamps. Consumers will thus be presented with a choice of options to replace GLS and other standard efficacy incandescent lamps. The minimum efficacy performance limits selected for this first tier will allow the continued use of:

- CFLi
- CFLn
- LFL
- IRC/xenon halogen
- LV halogen
- LEDs and other solid state lighting

In practice all but the CFLi and IRC/xenon halogen options, with the possible exception of future SSL options, would require new sockets to be installed and this is likely to steer the market towards the light source options using the same socket type in the near-term. The authorities intend that CFLi or equivalent performance lamps should become the dominant lamp but are mindful against introducing requirements if they phase-out lamps unless there is both a more efficient and viable alternative available. Accordingly the government intends to monitor the technological advances in lamps each year to determine the availability of more efficient and viable alternative lamps. In 2011 a review of options for a possible second set of requirements at 20 LPW level for 900 lumens initial flux will be conducted with a provisional target date of 2013. It is also anticipated that a second major tier of requirements will be implemented sometime from 2015 onwards with a provisional level of 35 LPW being considered.

3.3. Canada

Estimated GLS market volume in 2007:	~254 million units
Estimated CFLi market volume in 2007:	~41 million units
Mains power supply voltage	120 V

GLS figures include GLS-R, decorative, modified spectrum, vibration resistant, rough service and other minority incandescent lamps.
Note: there is considerable uncertainty about these figures as Canada is a lamp producer as well as a major importer and exporter of lamps.

The Canadian government made a policy commitment to phase-out incandescent lamps in March 2007 to enter into effect by 2012. The government is in the final stages of determining its regulatory requirements and Natural Resources Canada has prepared a draft regulation, which specifies that all lamps, except modified spectrum lamps, will be required to surpass a minimum efficacy limit of: Lamp efficacy (lumens/watt) = 4.0357 × ln (flux (lumens)) – 7.1345.

For modified spectrum lamps the required minimum efficacy limit is:
Lamp efficacy (lumens/watt) = 4.0357 × ln (lumen) – 8.3345.

The implementation of the requirements is phased across 2012 such that lamps with higher luminous flux must meet the standard earlier than those with lower flux (see Table 3.2).

Table 3.2. Proposed lamp MEPS schedule in Canada

Luminous flux	**Date standard must be met**
701-3 000 lumens	1/1/2012
200-700 Lumens	31/12/2012

In addition, all lamps would be required to have a rated life of > 1000 hours and a CRI of > 0.80.

As with Australia and the United States, the authorities have announced an intention of setting a more ambitious requirement in the future although an indicative level had not been announced

Although Canada shares a border with the United States and has a similar lamp market, there are a number of differences with the Canadian proposals and the adopted US requirements described below. The Canadian proposals express the performance threshold in terms of a non-linear efficacy per luminous flux function, which follows a very similar form to the Australian requirements albeit at a somewhat higher performance level. The Canadian performance threshold for most lamps is nominally 35% more ambitious than the Australian requirements for a 900 lm flux but is probably about 18% more stringent in terms of the technologies it prohibits when differences in power supply are taken into account, excepting modified spectrum lamps. The Canadian draft regulation differs from the US requirements in the following ways:

- Lamp performance requirements are set in terms of a minimum efficacy performance curve rather than via lumen bins and wattage caps.
- Requirements for modified spectrum lamps are more stringent *i.e.*, the limits are roughly 10% less stringent than for general lamps as opposed to approximately 25% in the United States.
- The United States has already specified additional minimum performance requirements to enter into force by 2020 whereas no proposal has yet been put forward in Canada.
- Canada's requirements apply to lamps with a luminous flux of 200 lumens to 3 000 lumens (*i.e.*, roughly to lamps with light output to standard GLS rated at 29 W to 150 W).
- Canada's proposal would phase-out the dominant 60 W GLS class two years faster than the US regulations.

Anticipated impacts on the future lamp market

Although the efficacy requirements as specified by the curve fall a long way short of requiring the most efficient types of screw-based lamps (*e.g.*, CFLi) they will have the effect of phasing-out all conventional GLS and halogen lamps. Consumers will thus be presented with a choice of options to replace GLS and other standard efficacy incandescent lamps. The minimum efficacy performance limits selected for the first tier will allow the continued use of the following:

- CFLi
- CFLn
- LFL

- IRC/xenon halogen
- LV halogen
- LEDs and other solid state lighting

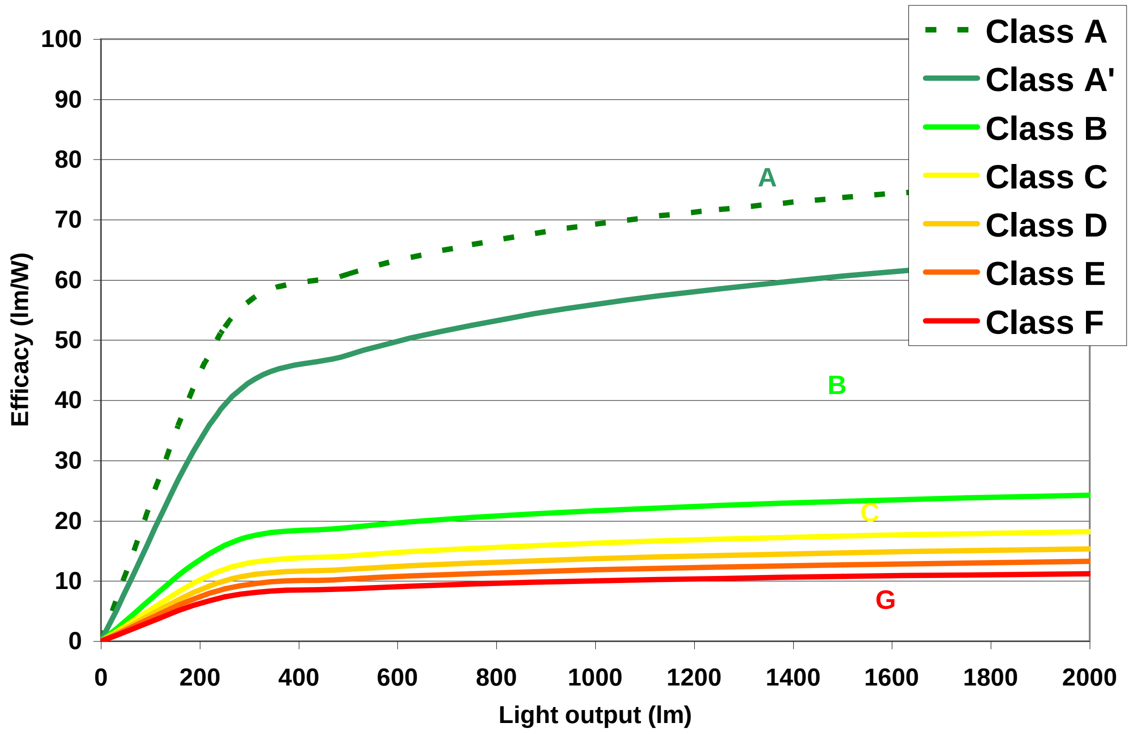
3.4. The European Union

Estimated GLS market volume in 2007:	~1 834 million units
Estimated CFLi market volume in 2007:	~475 million units
Mains power supply voltage	230 V

Note: GLS figures include GLS-R and decorative incandescent lamps.

EU heads of state announced a policy to phase-out incandescent lamps in the European Community in March 2007 and instructed the European Commission to prepare regulations, under the provisions of the Eco Design for Energy Using Products Directive, to come into effect no later than January 2009. Following the common process set out in that Directive the Commission hired consultants to produce a technical assessment and inaugurated a regulatory hearing process with EU member states. At the time the analysis in this study was first done the consultants' report had been received and preliminary discussions regarding possible efficacy levels had taken place. The Commission prepared a range of phase-out scenarios to inform the final decision and commissioned an additional analysis to determine the probable impacts of these scenarios.

Figure 3.2. Efficacy thresholds applied in the EU lamp label



The terms of reference for the initial ruling were limited to omni-directional light sources used in households, which restricts the final provisions to lamps that are distributed through general retail channels rather than through professional lighting channels. This is the same as the scope of labelling requirements for household lamps, which have been regulated since 1998 in the EU under the terms of the Energy Labelling Directive (98/11/EC). At the time of its development the performance thresholds applied in the EU label provided good distinctions between available lamp performance levels *e.g.*, CFLi were in the A/B range whereas halogen lamps could reach up to level C. However, with the advent of advanced halogen lamps, superior CFLi and SSL it is apparent that new classes will be required to better represent the full range of lamps on the market and the choices available to consumers. The EU Commission has also had work done on the options to redesign the performance thresholds being applied in the EU energy label; however, the phase-out options discussed below continue to reference the thresholds applied in the current label.

Anticipated impacts on the future lamp market

At the time the main analysis presented in this study was done, the European Commission was considering the following scenarios which are linked to the performance thresholds used in the EU energy label:

Table 3.3. Lamp phase-out scenarios that were considered in the EU

Name of the scenario	**Final class for lamps**	
	Clear	**Frosted**
Technical potential	A	A
Option 1	A	A
Option 2 HL-B	B	A
Option 2 HL-B/C	B/C	A
Option 2 HL-C	C	A
Option 3 (ELC)	C	C
BAU	None	None

The timelines considered were either for a phased (three stage) phase-out from 2009 to 2013 or for a slower phased (five stage) phase-out from 2009 to 2017 as shown for Options 1 and 3 below. These tables show the performance requirements expressed in terms of the minimum permitted energy label class from A to G, the lamp classes the requirements apply to (in the far left column) and the least energy efficient current lamp technology that would still be permitted for sale.

From these scenarios it is apparent that the weakest GLS phase-out outcome under consideration in the EU was for xenon HL level performance levels to be required for all mains voltage lamps by 2017 *i.e.*, that all conventional GLS would be phased-out by that time. The strongest requirements that were considered would have required CFLi efficacy levels by 2013. The eventual regulations adopted are discussed and analysed in the Afterword.

Table 3.4. Option 1: Slow

Present	2009	2011	2013	2015	2017
Requirements:	C except below 1000 lm	C except below 450lm	C (with CFL combination1)	C (with CFL combination1)	A (with CFL combination1)
GLS-C	Xenon HL-MV-LW (except below 1 000 lm)	Xenon HL-MV-LW (except below 450 lm)	Xenon HL-MV-LW	Xenon HL-MV-LW	CFLi (combination 1)
GLS-F	Xenon HL-MV-LW (except below 1 000 lm)	Xenon HL-MV-LW (except below 450 lm)	Xenon HL-MV-LW	Xenon HL-MV-LW	CFLi (combination 1)
HL-MV-LW	Xenon HL-MV-LW (except below 1 000 lm)	Xenon HL-MV-LW (except below 450 lm)	Xenon HL-MV-LW	Xenon HL-MV-LW	CFLi (combination 1)
HL-MV-HW (R7s)	Xenon HL-MV-HW	Xenon HL-MV-HW	Xenon HL-MV-HW	Xenon HL-MV-HW	CFLi (combination 1)
HL-LV	HL-LV	HL-LV	HL-LV	HL-LV	CFLi (combination 1)
CFLi	CFLi	CFLi	CFLi (combination 1)	CFLi (combination 1)	CFLi (combination 1)

Table 3.5. Option 1: Fast

Present	2009	2011	2013
Requirements:	C except below 450lm	C (with CFL combination1)	A (with CFL combination1)
GLS-C	CFLi (except below 450 lm)	CFLi (combination 1)	CFLi (combination 1)
GLS-F	CFLi (except below 450 lm)	CFLi (combination 1)	CFLi (combination 1)
HL-MV-LW	CFLi (except below 450 lm)	CFLi (combination 1)	CFLi (combination 1)
HL-MV-HW (R7s)	CFLi	CFLi (combination 1)	CFLi (combination 1)
HL-LV	HL-LV	HL-LV	CFLi (combination 1)
CFLi	CFLi	CFLi (combination 1)	CFLi (combination 1)

Table 3.6. Option 3: slow

Present	2009	2011	2013	2015	2017
Requirements:	D above 1 000 lm	C above 1 000 lm, D above 850 lm	C above 850 lm, D above 600 lm	C above 600 lm, D above 250 lm	C above 250 lm
GLS-C	Class D above 1 000 lm	As above	As above	As above	Xenon HL-MV-LW (above 250 lm)
GLS-F	Class D above 1 000 lm	As above	As above	As above	Xenon HL-MV-LW (above 250 lm)
HL-MV-LW	Class D above 1 000 lm	As above	As above	As above	Xenon HL-MV-LW (above 250 lm)
HL-MV-HW (R7s)	HL-MV-HW (R7s)	Xenon HL-MV-HW	Xenon HL-MV-HW	Xenon HL-MV-HW	Xenon HL-MV-HW
HL-LV	HL-LV	HL-LV	HL-LV	HL-LV	HL-LV
CFLi	CFLi	CFLi	CFLi	CFLi	CFLi

Table 3.7. Option 3: fast

Present	2009	2011	2013
Requirements:	C above 1 000 lm, D above 850 lm	C above 600 lm, D above 250 lm	C above 250 lm
GLS-C	As above	As above	Xenon HL-MV-LW (above 250 lm)
GLS-F	As above	As above	Xenon HL-MV-LW (above 250 lm)
HL-MV-LW	As above	As above	Xenon HL-MV-LW (above 250 lm)
HL-MV-HW (R7s)	Xenon HL-MV-HW	Xenon HL-MV-HW	Xenon HL-MV-HW
HL-LV	HL-LV	HL-LV	HL-LV
CFLi	CFLi	CFLi	CFLi

Individual EU Member State initiatives

Several EU member states announced a unilateral intention of phasing-out incandescent lamps within their borders. EU member states are constrained by EU Single Market regulations which require harmonised EU regulations for tradable goods. Nonetheless several EU member states announced policies to phase-out incandescent lamps within their borders, as summarised below.

France

Following a series of high profile fora on French environmental policy the government announced its support of a policy to phase-out incandescent lamps by 2010. No details were available regarding how this was to be achieved at the time the main study was conducted.

Finland

A draft bill was circulated in the Finnish parliament proposing to phase-out incandescent lamps by the beginning of 2011. The current status of this initiative is not known to the authors.

Ireland

The Irish government was working toward phasing-out incandescent lamps from 2009. They placed obligations on the public sector, which are required to only purchase efficient light sources. In addition, a parallel initiative to encourage consumers to purchase energy efficient bulbs by placing a levy on the standard incandescent bulbs was under developed. The intention is to save 700 000 tonnes of CO_2 emissions and reduce annual consumer electricity bills by EUR 185 million per year.

Portugal

New legislation imposing extra taxation on incandescent lamps was published on 12 April 2007 entered into force in early 2008. This introduced a EUR 0.5 tax on standard incandescent lamps. Halogen lamps, coloured incandescent lamps, reflector lamps and special lamps are exempted.

The United Kingdom

The UK government reached a formal agreement with the main UK lamp retailers to phase-out ordinary-shape (A-line) GLS lamps by the end of 2011. The agreed phase-out plan is as follows:

- By January 2008 retailers were to cease to replenish stocks of inefficient GLS lamps of 150 W and above.
- By January 2009 retailers were to cease to replenish stocks of inefficient GLS lamps of 100 W and above.
- By January 2010 retailers are to cease to replenish stocks of inefficient GLS lamps of 60 W and above.
- By January 2011 retailers are to cease to replenish stocks of all remaining inefficient GLS lamps and 60 W candle and golf-ball lamps.
- By 31 December 2011 retailers are to cease to sell all remaining inefficient GLS lamps and 60 W candle and golf-ball lamps.

This initiative is further supported by the Certified Emissions Reduction Target (formally the Energy Efficiency Obligation) under which utilities are required to achieve mandatory energy savings targets among household customers and which has led to substantial subsidies for high-quality CFLi and CFLn in the United Kingdom and a significant increase in market share for CFLs in general (Waide and Buchner 2008).

3.5. Japan

Estimated GLS market volume in 2007:	154 million units
Estimated CFLi market volume in 2007:	~27 million units
Mains power supply voltage	120 V

Note: GLS figures are from JELMA and include GLS-R, decorative and other minority incandescent lamps.

In December 2006 the JELMA (Japan Electric Lamp Manufacturers Association) announced the following four proposals to substitute less efficient lamps with higher efficiency alternatives:

- Incandescent Lamps to CFLi.
- Tungsten Halogen to Compact Fluorescent Lamps and Ceramic Metal Halide Lamps.
- Fluorescent Lamps to High-Frequency Fluorescent Lamps.
- High Pressure Mercury Lamps to Metal Halide and High Pressure Sodium Lamps.

Throughout 2007 the government and lamp manufacturers made a strong sales promotion for CFLi which was rewarded with a sales increase of 22%.

On 5 April 2008 Mr. Amari, the Minister of the Ministry of Economy, Trade and Industry (METI) announced "the replacement policy for Incandescent to CFLi by 2012". Regulations were understood to be under preparation within the rubric of the Top Runner programme; however, details were not available at the time the main body of the analysis was done. In addition some of the major Japanese lamp manufacturer's have announced a target of full replacement of GLS to CFLi by 2010.

Anticipated impacts on the future lamp market

In the absence of detailed regulations it is premature to determine the impacts of the new policy; however, JELMA reports that approximately 70% of Japanese standard E26 base lamps will be replaced by CFLi. Those that remain will be specialty lamps *i.e.*, those used for dimming, spot lighting and decorative purposes (Sun, 2008).

3.6. The United States

Estimated GLS market volume in 2007:	~2441 million units
Estimated CFLi market volume in 2007:	~476 million units
Mains power supply voltage	120 V

Note: GLS figures include GLS-R, decorative, modified spectrum, vibration resistant, rough service and other minority incandescent lamps.

When the Energy Independence and Security Act of 2007, entered into law on 19 December 2007, the United States became the first OECD country to pass legislation specifying how incandescent lamps were to be phased-out. The regulations set maximum permitted lamp power levels as a function of luminous flux that enter into force between 1 January 2012 and 1 January 2014. These have the effect of phasing-out the most common standard screw base incandescent household lamps (GLS A-line) including clear, frosted, soft white, and daylight (*i.e.*, modified spectrum) lamps, but exempt specialty coloured and shaped lamps. In terms of timing: after 1 January 2012, the most common 100 W incandescent lamps cannot be manufactured or imported for sale; after 1 January 2013 the most common 75 W lamps are phased-out, while after 1 January 2014 the most common 60 W and 40 W lamps are excluded. The legislation also specifies minimum efficacy levels to come into effect from 2020 onwards of 45 LPW or higher (a rulemaking is to be undertaken in 2014 to determine whether the levels should be any higher than 45 LPW, but not lower).

To minimise the potential for "loopholes" to be exploited the sales of exempted less common incandescent lamp types is to be tracked and if sales of any of these types double, then maximum wattage restrictions will be placed on them. The types to be monitored are:

- Rough service
- Vibration service
- 3-way
- 150 W (2 601to3 300 lumen lamps)
- Shatter-resistant

The details of the regulations are as follows.

The regulations apply to incandescent or halogen lamps:

- Intended for general service applications.
- With medium screw bases (E26).
- With a lumen range of 310 to 2 600 (40 W to 100 W in today's wattages)
- Capable of operating in range of 110 V to 130 V.

In addition the power rating of candelabra base (E11 and E12) incandescent lamps shall not exceed 60 W and of intermediate base incandescent lamps (E17) shall not exceed 40 W.

Table 3.8. US General service incandescent lamp MEPS and effective dates

Approx. rated power in 2008 (W)	Rated Lumen Ranges	Maximum permitted Rate power Wattage (W)	Effective Date	Minimum permitted life (hours)
100	1 490-2 600	72	01-01-12	1 000
75	1 050-1 489	53	01-01-13	1 000
60	750-1 049	43	01-01-14	1 000
40	310-749	29	01-01-14	1 000

Source: OSI (2007).

The lumen ranges applying to modified spectrum lamps (daylight lamps) are 25% lower and have the same maximum wattages as listed in Table 3.8.

Affected lamps must have a minimum CRI of 80 except for modified spectrum, which will have a minimum CRI of 75.

In addition to the requirements mentioned above, the scope of existing MEPS applied to incandescent reflector lamps have been extended to cover a broader class of reflector lamps including bulged reflector (BR) lamps. The main impacts are the following:

- 65 W BR30 lamps, commonly used in homes and restaurants, may still be manufactured and sold.
- 120 W BR40 lamps, used mostly in commercial and retail applications, will not be allowed and should be replaced with more efficient halogen PAR lamps.

Anticipated impacts on the future lamp market

Although the specified power requirements fall a long way short of requiring the most efficient types of screw-based lamps (*e.g.*, CFLi), they will have the effect of phasing-out all conventional GLS and halogen lamps. Consumers will thus be presented with a choice of options to replace GLS and other standard efficacy incandescent lamps. The minimum efficacy performance limits selected for the first tier will allow the continued use of:

- IRC/xenon halogen
- CFLi
- LEDs and other SSL

Post 2020 the backstop requirements are at a level that can only be met by CFLi or SSL thus IRC/xenon halogen technology would appear to have an eight year window on the US market. Furthermore, a new rulemaking is scheduled for 2014 to review and possibly amend these regulations, as well as requirements applying to CFLs, LEDs and OLEDs, thus the stringency of the requirements could be increased at that time.

California and Nevada

In general, individual US states cannot adopt standards for general service incandescent lamps that are different from the federal standards. However, there is one set of exceptions:

- California has less strict standards for these bulbs, which entered into force on 1 January 2008; and can remain in effect until the federal standards enter into force.
- California and Nevada are permitted to adopt the new federal incandescent lamp standards beginning in 2011 instead of 2012; however, the phasing intervals must be maintained.

3.7. The rest of the OECD

Switzerland and Norway

Switzerland

Switzerland has announced a policy of phasing-out incandescent lamps by 2012 and the Swiss authorities have prepared a draft regulation setting out how this could happen that links the steps to energy label classes applied in the EU energy label, which is also adopted in Switzerland. The Swiss Federal Office for Energy announced in mid-2007 a plan to publish a federal decree prohibiting the sale of lighting products with an EU Energy Label class of F or G starting at the beginning of 2008. In order to subsequently achieve a full ban of incandescent lamps, it is planned to add further Energy Label classes in a second tier. Very low power and reflector lamps are exempted from this proposal.

Discussions have since taken place with industry associations and in early 2008 a decision about the final regulatory structure to be adopted had not yet been taken. It is possible the final regulation will be informed by the parallel developments in the EU.

Norway

At the time of writing Norway had not formally announced a policy to phase-out incandescent lamps but was understood to be considering options. In general Norway harmonises its equipment efficiency requirements with EU legislation and is therefore likely to follow the EU policy.

Korea

Korea has succeeded in greatly increasing CFLi sales at the expense of GLS over the last few years driven in part through promotional schemes and subsidies. As a result GLS sales have declined from

56 million units in 2000 to 27 million in 2006. Korea is also the first country to have imposed efficiency performance requirements on incandescent lamps and in December 2008 Korean government decided to phase-out incandescent lamps (except something for special purposes) by the end of 2013. The stringency of MEPs applying to GLS will be increased and revision of related regulation is under way.

GLS market volume in 2007:	27.1 million units
CFLi market volume in 2007:	17.0 million units
Mains power supply voltage	230 V

Source: KEMCO (2008).

3.8. The Philippines and Thailand

The Philippines

It is estimated there are about 90 million lighting points in the country with an E27 base of which 68 million are fitted with incandescent bulbs and the rest with CFLi. Annual GLS sales are thought to be about 40 million lamps.

At the 2008 Philippines Energy Summit President Ahora made a formal policy announcement that the Philippines would aim to phase-out incandescent lamps by 2010. The Department of Energy intends to issue the formal regulations by the end of 2008 and has begun their preparation. Supporting measures will include the following (Huliganga, 2008):

- An “Energy Efficiency in Lighting Program”
- Retrofit of government buildings
- Nationwide distribution of CFLs
- Public lighting retrofit
- Lamp waste management
- Other efficiency initiatives
- Product testing
- Energy efficiency pilot financing facility
- Efficient building initiative
- Communication and social mobilization
- Communication for efficient lighting
- Promoting efficiency in everyday life

Anticipated impacts on the future lamp market

Details of the pending regulations are not yet available; however, the DOE has estimated that the benefits would include the following (Huliganga 2008):

- USD 2 million savings in avoided peak power generation demand of at least 2 000 MW.
- PhP20B (USD 500 million) savings for the consumers each year or about PhP7 per night per household.
- 2.5 Mt of avoided CO_2 emissions per year.

25 million CFLi are reported to have been sold in the Philippines in 2005.

Thailand

15 million CFLi and 30 million GLS are reported to have been sold in Thailand in 2006 (Asawutmangkul, 2008). Thailand adopted a policy of phasing-out GLS in 2007 but is understood to be pursuing a voluntary approach rather than a regulatory one at present. This involves increasing the magnitude of Thailand's CFLi subsidised or free distribution programme run by the state utility EGAT. The first stage involved the purchase and distribution of 800 000 CFLi by the end of 2007. The intention is to make 30 million CFLi available to Thai consumers at very low prices over the 2008 to 2030 time frame.

3.9. Latin America

Argentina

Legislation prohibiting the import of single coil incandescent lamps (the least efficient type of incandescent lamp) was published on 14 June 2007 and entered into effect in June 2008. In addition, draft proposals for more sweeping minimum energy performance standards applying to incandescent lamps were under preparation and may entail a broad regulatory ban on incandescent lamps.

Argentina is believed to have accepted an offer of several million stocks of CFLi offered by Cuba to trial the phase-out of GLS by voluntary direct substitution. It is also understood that the government has expressed an interest to develop a domestic CFL industry in Argentina.

Brazil

Despite having an established history of high CFLi usage Brazil is still a major consumer of incandescent lamps. There is understood to have been a move in the Brazilian congress to introduce regulations to phase-out incandescent lamps from 1 January 2010, which would be prepared by ANEEL (National Agency of Electrical Energy). The draft bill was under consideration by the Mining and Energy Commission of the House of Representatives in Brasília, which proposed a public hearing to discuss the issue. If approved by the House of Representatives, the draft bill would be sent for discussion in the Senate House and, if approved there, would require the final signature of the President of Brazil before entering into force.

Bolivia

Bolivia is receiving support from Cuba and Venezuela to phase-out GLS lamps and has an initial target to directly substitute 5 million GLS in Bolivian households. Bolivia is spending USD 1.7 million on administrative measures to support this programme. The lamps are understood to be supplied by Cuba and Venezuela but are of Chinese origin.

Colombia

Columbia passed a presidential decree in June 2007 requiring GLS lamps in public buildings to be replaced by CFLi by the end of 2007. It is understood Columbia plans to phase-out incandescent lamps in all sectors and draft legislation has been published that aims to prohibit the manufacture, import or sale of GLS lamps in Colombia with effect from mid-2010. As with other countries in the region Colombia has been offered stocks of CFLi by Cuba to support this objective. Colombia has incandescent production facilities operated by some of the major international lamp producers.

Ecuador

The Ecuador government is reported to be implementing a programme to substitute 600 000 GLS lamps by CLIi and then aims to follow this with a substitution programme for 6 million GLS.

Venezuela

With support from Cuba, Venezuela began to phase-out incandescent lamps via direct substitution programmes in November 2006. As of April 2007, the Ministry of Petroleum and Energy (MINPET) of Venezuela reported that the first phase of this project led to 53 million incandescent lamps being replaced by CFLi and had led to a reduction in peak power demand of 1 400 MW nationally and 2 486 GWh of electricity savings. In the next stage of the programme, the authorities planned to replace 15 million GLS lamps with CFLi in the commercial buildings sector.

3.10. Other economies

China

GLS market volume in 2007:	~2 786 million units
CFLi market volume in 2007:	~1 000 million units
Mains power supply voltage	230 V

Source: CALI (2008).

China is considering options for the phase-out of incandescent lamps and has launched a new project to assess the options with support from the GEF; however, China has not yet committed to a full regulatory phase-out policy. The project is set to be a major element informing China's future policy choices on this topic. This builds upon earlier lighting efficiency projects supported by the GEF including the Green Lights China Programme, which helped develop capacity for the production and testing of high efficiency lamps in China and led to the development of several lighting efficiency regulations applying to non-incandescent lamp types. Major CFLi promotional programmes were initiated in 2007 and the government introduced measures to encourage public authorities to only procure efficient lamp sources. Among other initiatives the Ministry of Construction announced the Eleventh Five-Year Plan in July 2006, in which it said that the Chinese government planned to have 150 million energy-saving lamps installed in hotels, office buildings and residential buildings.

India

Like China, India has begun to consider policy options to move away from incandescent lamps but is not thought to be poised to take a decision to phase them out at present. Nonetheless there are a number of large scale CFLi promotional campaigns underway in various parts of the country and sales of CFLi have been growing by 60% per year over the last few years and reached 300 million units in 2008, up from 165 million in 2007 (Sujan 2008).

Tunisia

Tunisia is understood to be developing regulations to phase-out incandescent lamps. No details were available at the time of writing.

3.11. Global initiatives

In addition to specific national initiatives there are two globally focused initiatives to support high efficiency lighting objectives:

The UNDP, UNEP and GEF have launched a high profile global initiative to support the phase-out of incandescent lighting in non-OECD economies. Its initial focus is to work with China to provide industrial and policy support to assist an accelerated migration away from incandescent lamps. A multi-million US dollar programme is being developed. In the medium-term the intention is to reach out to other economies and offer them support to phase-out GLS.

The Energy Efficient Lighting Initiative (ELI) is an international lighting quality testing and certification programme. It establishes lamp quality criteria and provides third party testing and certification to verify that products meet high-quality performance requirements. ELI also provides important technical and testing support to economies implementing efficient lighting programmes.

4. International lamp markets and projected demand for regulatory compliant lamps

Synopsis

The analysis of international market data conducted for this study shows there has already been an astonishing and accelerating transformation away from GLS as a proportion of screw-base lamp sales, which has been accelerating year on year. Despite steady gains in market share for halogen lamps by far the greatest increase in market share has been for CFLi. Evidence of a marked increase in CFLi sales that was detected in sales data running up to 2004 in the IEA 2006 global lighting assessment *Light's Labour's Lost* (IEA, 2006) has shown a dramatic and unexpected acceleration since. The trend appears to be the same in all markets, both within the OECD and beyond.

This is good news from a public policy perspective because it illustrates that the broad market transformation goals behind the move to phase-out general service incandescent lamps are already on the way to being realised despite the regulations not yet coming into effect and in many cases still awaiting issue. However, it greatly complicates the analysis of the impacts of the pending regulations on market demand for CFLi because the base-line market trajectory has rapidly departed from previous trends.

Data sources and types

The data used in this analysis comes from several complementary sources. Direct market data on lamps sales was supplied by leading manufacturers' associations for the OECD, China and India. Information on lamp imports and exports was derived from the global Comtrade database managed by the World Bank. In the case of the EU lamp production and import/export data was also available from Eurostat's PRODCOM database. For some other economies direct expert and industry contact was sought to establish production and market volumes. In addition, data from a number of general market research reports were utilised. Lastly, numerous complementary studies on the installed lamp base within particular economies was utilised for most of the OECD economies, China and some other markets. In many cases this included information on the number of lamps by type and the hours of use, from which it was possible to establish benchmarks with which to verify and or calibrate the IEA lighting stock model. Literally thousands of individual data points have been entered into this model, which serves not only as a vehicle to make future lamp demand, energy and emissions scenarios but also as a means of reconciling disparate data sets in order to have confidence in the overall market picture.

4.1. Current trends in GLS and CFLi lamp sales

Global demand for GLS

It is estimated that global demand for GLS was about 12.5 billion lamps in 2007 and 562 million for GLS-R as shown in Table 4.1. The term GLS is applied in the broader sense in these figures and includes all major types of incandescent lamp used for general illumination in screw or bayonet sockets *i.e.*, also decorative and other lamps such as daylight, vibration resistant, etc. This value has been reasonably stable over the last few years *e.g.*, global consumption of GLS in 2003 was estimated at 13.1 billion lamps and in 1997 it was approximately10 billion (IEA, 2006).

Table 4.1. Estimated global sales of GLS lamps in 2007 (Unit: million)

Region	**GLS**	**GLS-R**
United States and Canada	2 521	174
EU27, Norway and Switzerland	1 731	168
Latin America and Mexico	900	10
Former Soviet Union, non EU Europe and Turkey	1 400	50
China	2 786	40
Rest of Asia	1 700	70
Middle East, Africa and Rest of World	1 500	50
Total	12 539	562

Source: IEA estimated.

Trends in OECD screw-based lamp sales

In OECD markets the trend for GLS sales is now in decline after 120 years of increase. Sales in IEA member economies peaked in 2001 and have decreased at an average of 2.8% per year since (Table 4.2). Total sales in 2007 were 16% lower than 2001 and declined by over 5% per year from 2005 to 2007.

Table 4.2. Estimated sales of GLS in IEA economies (Unit: million)

	IEA +EU9	EU27 +IEA2	USCAN	ANZ	Japan/Korea
2000	5 264	2 253	2 766	64	181
2001	5 318	2 230	2 856	64	169
2002	5 178	2 206	2 755	63	155
2003	5 137	2 088	2 834	48	166
2004	5 133	1 968	2 962	54	149
2005	4 961	1 849	2 894	57	161
2006	4 674	1 747	2 700	65	162
2007	4 455	1 731	2 521	43	160

Note: IEA+EU = IEA member economies plus additional 9EU members who not are not IEA members; EU27+IEA2 = EU + Switzerland and Norway; USCAN = United States + Canada, ANZ = Australia + New Zealand.
Source: IEA estimated

GLS-R sales are slightly less than one-tenth of those for GLS in OECD markets and peaked in 2004; however, since then they have declined at a faster rate than for GLS as a whole. Sales dropped by 6.7% per year from 2004 to 2007 (Table 4.3) and fell by 34 million in 2007.

Table 4.3. Estimated sales of GLS-R in IEA economies (Unit: million)

	IEA+EU9	EU27+IEA2	USCAN	ANZ	Japan/Korea
2000	491	285	180	6	20
2001	475	292	158	6	19
2002	492	303	166	6	17
2003	503	304	175	5	19
2004	457	246	189	6	17
2005	438	188	225	7	18
2006	403	171	205	10	18
2007	369	168	174	9	18

Note: IEA+EU = IEA member economies plus additional 9EU members who not are not IEA members; EU27+IEA2 = EU + Switzerland and Norway; USCAN = United States + Canada, ANZ = Australia + New Zealand.
Source: IEA estimated.

Part of the decline in GLS-R sales is explained by an increase in halogen lamp sales, which grew by an average of 3.2% per year in IEA economies from 2000 to 2007.

Halogen lamps have a higher share of the OECD 230 V markets than the 120 V markets but on average account for 13% of GLS sales by volume (Table 4.4). Halogen lamp sales for general illumination showed modest increases over the same time frame with average annual growth rates of 3.2%; which amounts to a growth of about 34 million lamps a year. However, the lifespan of halogens is between 1.5 and 4 times that of GLS and so these sales translate into a higher proportion of occupied socket time than for GLS.

Table 4.4. Estimated sales of Halogen lamps in IEA economies (Unit: million)

	IEA+EU9	EU27+IEA2	USCAN	ANZ	Japan/Korea
2000	474	238	158	10	67
2001	484	245	168	11	59
2002	483	255	168	11	48
2003	512	276	176	12	49
2004	541	287	196	15	42
2005	549	298	198	16	37
2006	555	314	189	17	34
2007	577	342	186	18	31

Note: IEA+EU = IEA member economies plus additional 9EU members who not are not IEA members; EU27+IEA2 = EU + Switzerland and Norway; USCAN = United States + Canada, ANZ = Australia + New Zealand.
Source: IEA estimated.

The dramatic changes in OECD screw-based lamp markets have occurred for CFLi. Sales increased from 135 million to over 1 billion in 2007. Furthermore the rate of increase in sales has been accelerating. From 2000 to 2002 sales growth was about 12.5% per year, from 2003 to 2005 it was

29% but from 2005 to 2007 it has been a staggering 73%. CFLi sales growth has been very pronounced across the OECD but has been highest in Europe, North America and Australasia (see Table 4.5).

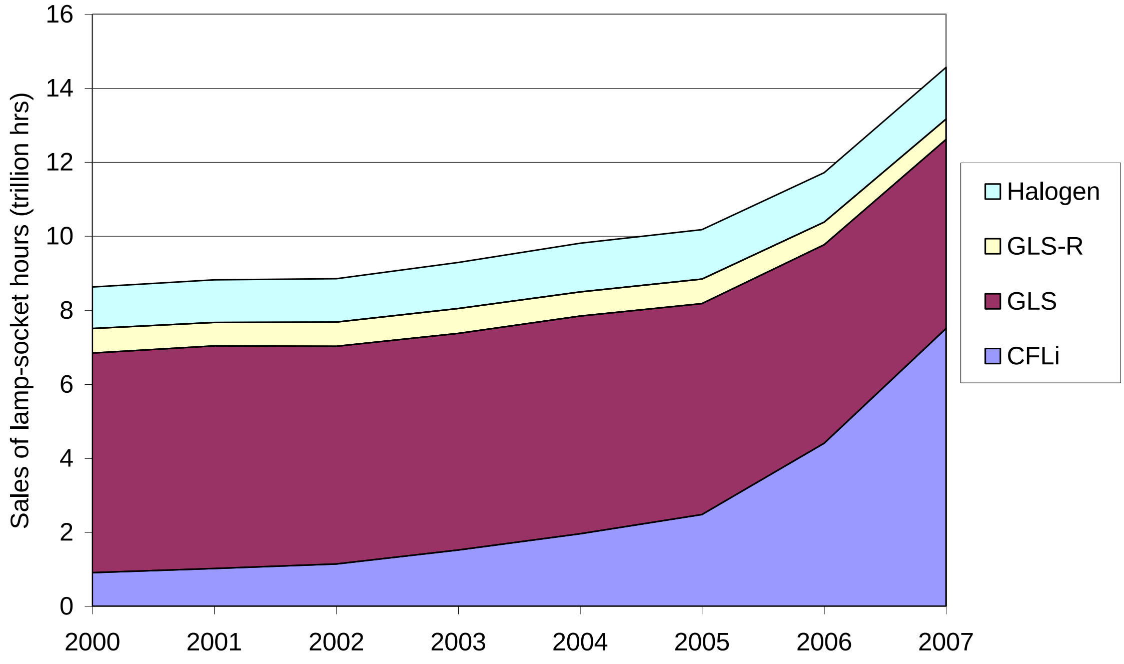
Table 4.5. Estimated sales of CFLi in IEA economies (Unit: million)

	IEA+EU9	EU27+IEA2	USCAN	ANZ	Japan/Korea
2000	135	68	47	1	20
2001	153	75	54	1	23
2002	171	78	62	2	29
2003	218	82	103	4	29
2004	280	98	142	5	35
2005	360	153	163	7	37
2006	639	319	267	13	40
2007	1 072	483	517	27	46

Note: IEA+EU = IEA member economies plus additional 9EU members who not are not IEA members; EU27+IEA2 = EU + Switzerland and Norway; USCAN = United States + Canada, ANZ = Australia + New Zealand.
Source: IEA estimated

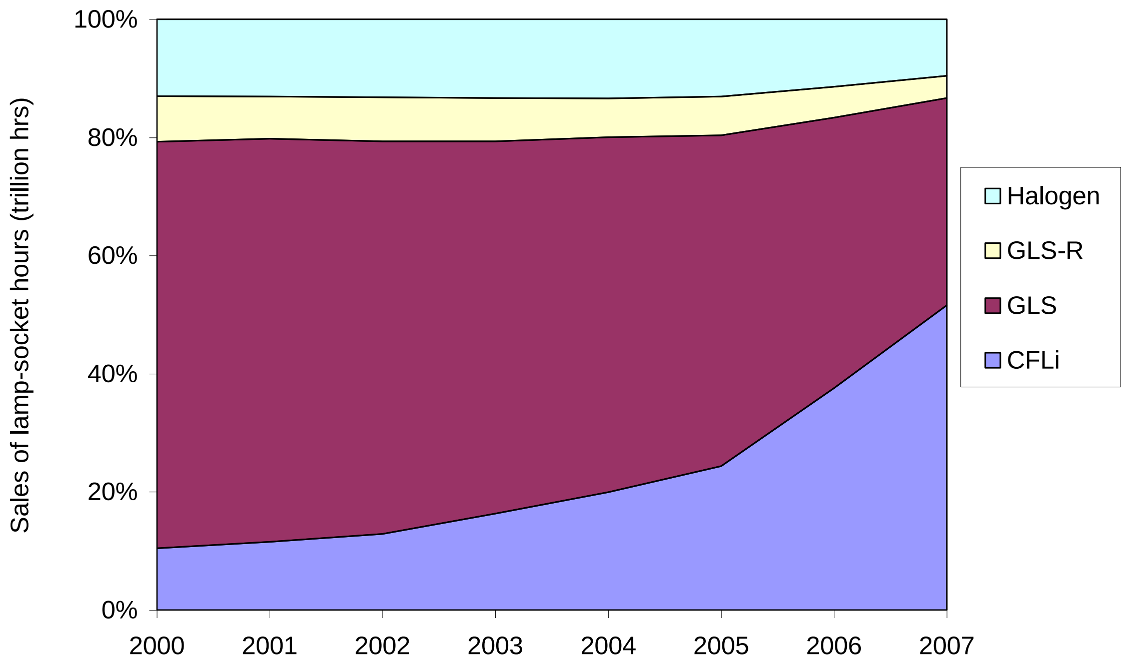
The real impact of these sales shifts is seen when the implications in terms of lamp socket hours are considered. The average lifespan of CFLi sold in IEA economies is estimated to be about 7 000 hours (*e.g.*, with about 6 000 hours in Europe and about 8 000 hours in the United States), while the average GLS life is about 1 140 hours (*e.g.*, about 1 000 hours in Europe and 1 250 hours in the United States). This means that to occupy a single light socket will require over six times as many GLS lamps to be sold as for CFLi. Looking at socket hour sales is therefore a good indicator of future socket occupancy levels. In IEA member countries, total sales of screw-base lamp socket hours increased from 8.4 trillion in 2000 to 14.3 trillion in 2007 while the part taken by CFLi increased from under 1 trillion socket hours to over 7 trillion over the same period, Figure 4.1. On this basis the share of socket hour sales taken by CFLi overtook the combined socket-hour share of GLS, GLS-R and halogen lamps in 2007, Figure 4.2. Of course these levels need to be maintained year on year to translate into comparable lamp stock shares and so this is a leading indicator of future lamp stock shares. Furthermore screw-base lamp stocks are not likely to grow anywhere near as rapidly as the lamp socket hours sales might imply at first viewing. The annual average growth rate in socket hours was 2.5% from 2000 to 2003, 5.3% from 2003 to 2005, 15% in 2006 and 24% in 2007. Long-term growth in screw-base lamp stocks has been between 0% and 5% per year in OECD economies, so clearly a rapid transition is taking place where high turnover rate lamps such as GLS are being replaced by much longer life CFLi. This will quickly lead to much reduced future sales of GLS and also necessitate a sharp slow down in future CFLi sales growth as the opportunity for lamp sockets to be filled for the first time by CFLi diminishes and the replacement market (*e.g.*, to replace retired CFLi) begins to take a larger share of total CFLi sales. As the average CFLi lasts six times as long as the average GLS in OECD member countries the long-term volume of the lamp replacement market will be proportionately lower than for GLS.

Figure 4.1. Sales of lamp socket hours by screw-base lamp type in IEA economies



Source: IEA estimated.

Figure 4.2. Share of lamp socket hours by screw-base lamp type in IEA economies

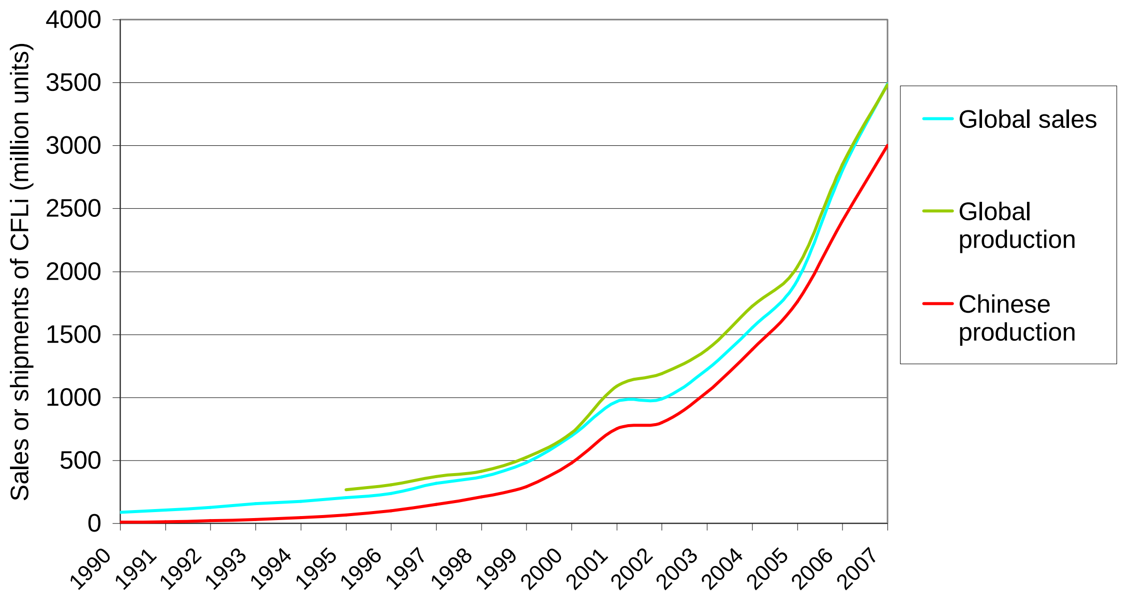


Source: IEA estimated.

Global production and demand for CFLi

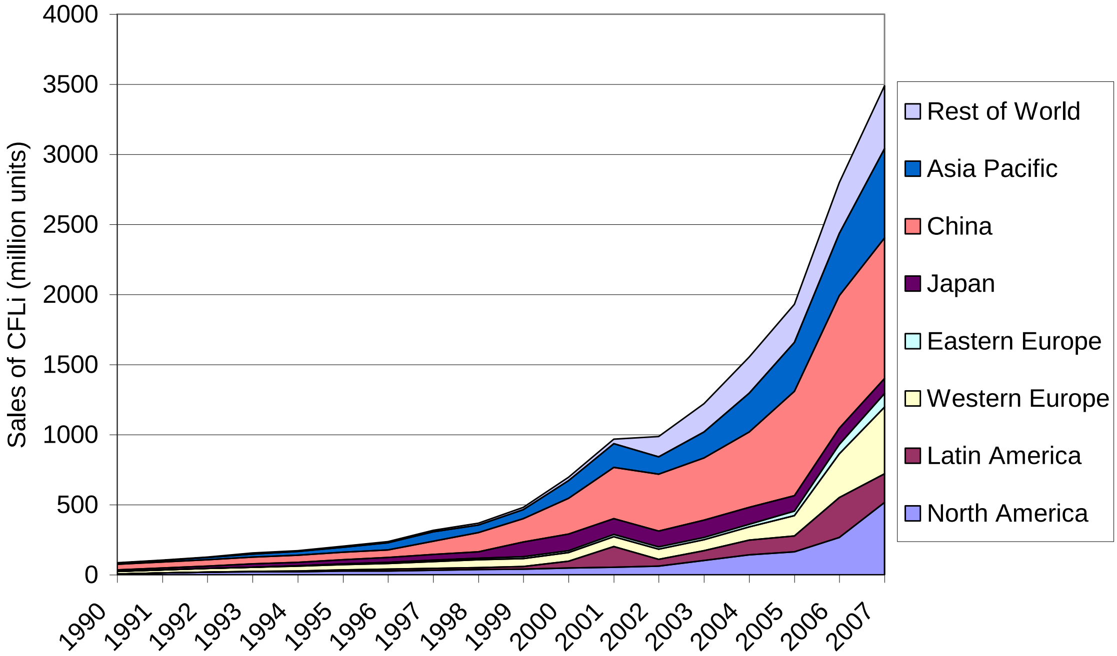
China has dominated CFLi production for more than a decade; over 80% of CFLi are produced in China. Production also takes place in Europe, Japan and Korea, with new production centres emerging in countries such as India, Indonesia, the Philippines, Egypt, Dubai and South Africa. While the data on production available for this study is not complete it is in reasonably close correspondence with the data on sales, imports and exports. Figure 4.3 shows estimated global sales, global production and Chinese production of CFLi. Figure 4.4 shows the estimated sales of CFLi by region. From this it is clear that China is not only the dominant producer but is now comfortably the largest single market, accounting for sales of about 1 billion lamps in 2007, which is about the same as for the combined IEA economies. Another 1.5 billion lamps are sold in the rest of the world with the dominant markets being the rest of Asia, Latin America and the Middle East. These sales trends illustrate that the huge transformation in the screw-based lamp market that has been taking place in IEA member countries has also been occurring across the world. The annual average growth rate in CFLi sales between 2000 and 2007 in IEA countries was 34%; 22% in China, 23% in Latin America, 33% in Eastern Europe, 26% in Asia Pacific and 56% in the Rest of the World, giving a non-OECD annual average growth rate of 23% across the period. The growth in sales in OECD member countries has been particularly fast over the last two years, however, and it appears this may be in response to an even greater increase in market awareness of the benefits of CFLi perhaps linked to the extra awareness raised through the regulatory process.

Figure 4.3. Sales and production of CFLi



Source: IEA estimated.

Figure 4.4. Estimated CFLi sales by region



Source: IEA estimated.

4.2. CFLi life expectancy, quality and future lamp stocks

Not all CFLi are equal. Some last much longer than others and there are important quality distinctions linked to light quality, warm-up time, lumen maintenance and several other factors. The lifetime alone has a large impact on the sale of socket hours thus a CFLi that lasts twice as long as another is effectively equivalent to two of the shorter life CFLs in terms of socket occupancy. Lifetime is thus a pivotal factor when considering the influence of the unit sales on the composition of the future installed lamp stock. There is no comprehensive global assessment of CFLi lifetimes by region but various studies and fora have addressed this topic. For example, a recent study looking into CFLi quality in Asia found that a large proportion of CFLi sold in the region are low-quality lamps. In China, for example, it has been estimated that about 45% of lamps are of export quality or higher, about 40% are of intermediate quality lasting from between 3 500 and 6 000 hours and about 15% last for less than 3 500 hours. In India, the shares have been estimated at 60%, 10% and 40% respectively. In the Philippines the figures are 68%, 8%, 24% respectively (USAID 2007). These values compare to an OECD average CFLi lifespan of about 7 000 hours. Based on these figures and a reconciliation of stock and sales data in China it is estimated that the average CFLi in the current Chinese stock will last for 4 200 hours. There is no means of knowing at present what the figures are in other regions but if it is assumed that the estimated average Chinese lamp life expectancy is repeated throughout the non-OECD world it is possible to derive estimates for global sales of CFLi lamp socket hours in 2007 of 17.7 trillion lamp hours, which is roughly 1.56 times greater than for GLS. As recently as 2003, global CFLi sales of lamp socket hours were only 13% of those for GLS.

In OECD member countries, the trend in recent years has been towards high lamp quality and lifespan and many of the actual or draft regulations phasing-out GLS make enhanced CFLi quality requirements mandatory. Thus there will be pressure to increase CFLi life expectancy as well as volumes in response to the phase-out of GLS. In non-OECD countries, attention is also increasingly focused on lamp life expectancy and thus it is anticipated that CFLi quality requirements will rise around the world in response to the new regulatory dynamics. When considering future demand for CFLi the question is as much how much demand at what quality level as how much demand in total number of lamps. Discussions with the leading lamp industry experts in the OECD and in China have confirmed that there is plenty of capacity available to produce low-quality CFLi but for high-quality CFLi demand is near to production capacity at present.

Various estimates of the global market for "good quality" CFLi put it at between 1.2 and 1.4 billion lamps for 2007; however, there is no single definition of what good quality is. If the characteristics of lamps sold in the OECD are considered to be "high quality" the data implies that between 20 and 40% of the lamps of equivalent quality to those sold in the OECD are sold in non-OECD markets at present. There is still a very large difference in the quality of the remaining portion of the global CFLi market, however, and in the case of lamp lifespan this encompasses levels near to 6000 hours at the higher end to less than 2000 at the lower.

5. Projecting the impacts of future GLS phase-out regulations

5.1. Development of the model and phase-out scenarios

The lamp sales and lifespan data presented above has been entered into the IEA global lighting energy model originally developed for use in the 2006 IEA publication *Light's Labour's Lost: Policies for Energy-Efficient Lighting*. The original model divided the world into the following regions: United States and Canada, OECD Europe, Japan and Korea, Australia and New Zealand, China, the Former Soviet Union and the Rest of the World. The revised version includes separate elements for the United States, Canada, Japan and Korea and in the case of Europe has been modified to add all EU countries to the IEA European countries. In each of these regions separate modules are used to analyse lighting energy and lamp demand in the residential and non-residential lighting sectors. The model is a type of lamp stock model that has inputs for each type of screw-based incandescent lamp (GLS, GLS-R, decorative and other) and for competing technologies such as CFLi, seven types of indoor halogen lamps and LEDs. Time dynamic lamp stocks are derived for each lamp type and sector and are used to determine overall lamp stocks, illumination levels, energy use, CO_2 emissions and lamp volume demand. The model is calibrated against numerous different data types including: lamp sales volumes (discussed in aggregate above), lamp operating hours, life expectancy and retirement functions, efficacy and power ratings. The predicted results are further calibrated against known snap shots of lamp stocks in each particular economy to help identify and address any anomalies in the data or its analysis.

Establishing the future scenarios

The original intention was to establish reference case and phase-out scenarios to determine the difference in lamp demand between the two and in particular to establish the profile of international CFL demand under the various phase-out scenarios. In conducting the analysis, however, it has become apparent that there is huge uncertainty regarding the reference case scenario in all economies because for the reasons explained in Section 4 the market has clearly entered a new paradigm that entails highly unpredictable sales trajectories. Furthermore, it is clear that the regulations will be coming into force in almost all economies at a time when demand for high efficacy screw-based lighting will be much higher than it was at the time that public policy to phase-out incandescent lamps was first conceived and adopted. There has clearly been some influence of the public policy pronouncements on the demand for higher efficacy lamps but it is impossible to reliably separate this from other factors that may be stimulating a sudden increase in accelerated demand. Accordingly reference case scenarios have been established but there is only limited confidence in their reliability.

Of greater importance for this study is the development of the demand profiles for higher efficiency lighting in response to the implementation of phase-out regulations. These come into two types:

- Those that are based upon known regulations.
- Those that are speculating about future regulations.

As regulations have been published for the United States and were known in detail for Australia and Canada these countries fell into the first category, albeit that in all three countries there is some degree of uncertainty with respect to possible second tier requirements. The timing and intent of Japan's policy was also known and thus an attempt has been made to transpose this into a phase-out schedule with given degrees of stringency based upon the expressed intent. Among the OECD countries the greatest uncertainty pertained to the EU, which was clearly committed to phasing-out incandescent lamps but was exploring a range of options with schedules beginning as early as 2009 and ending as late as 2017 when the analysis was done. As the purpose of this study is to determine if there are likely to be any sharp increases in regulatory-driven demand for CFLi that might lead to shortages a higher priority was given to analysing the more ambitious scenarios.

Assumptions about market responses to phase-out regulations by country

Australia

The minimum efficacy performance limits selected for the first tier will allow the continued use of the following:

- CFLi
- CFLn
- LFL
- Xenon and IRC/xenon halogen
- LV halogen
- LEDs and other solid state lighting

In practice all but the CFLi and xenon or IRC/xenon halogen options, with the possible exception of future SSL options would require new sockets to be installed and this is likely to steer the market towards the light source options using the same socket type in the near-term. Accordingly the assumptions made in this analysis on the post Tier 1 regulatory lamp market shares for GLS replacements are as follows:

- CFLi: 62% of the non-solid state GLS replacement market falling to 58% in 2012.
- Xenon halogen lamps: 38% of the non-solid state GLS replacement market rising to 40% in 2012.

For GLS-R replacements and for replacements for standard mains voltage halogen screw or bayonet-base lamps it is assumed that:

- CFLi: 50% of the non-solid state GLS replacement market.
- Xenon halogen lamps: 50% of the non-solid state GLS replacement market using reflectors if substituting for a reflector lamp but not otherwise.

For linear (double-ended) halogen lamps it is assumed that:

- 50% are replaced by separate ballast CFL torchiere lamps and that 50% of the market is displaced in favour of other lighting solutions.

For mains voltage halogen capsule lamps it is assumed that:

- 100% of models that do not meet the requirements are replaced by xenon halogen capsule lamps.

Although the authorities intend that CFLi or equivalent performance lamps should become the dominant lamp and aim to review options in 2011 regarding a potential 35 LPW performance limit this is not assumed in the phase-out scenario considered here.

Solid state lighting is assumed to gradually take market share from all types of traditional screw-based lamps but beginning first with directional light sources such as halogen reflector lamps and GLS-R lamps. The share of new screw-based lamp socket hour sales taken by SSL reaches 9% by 2020 and 41% by 2030.

Canada

The phase-out scenario considered for Canada looks at the impacts projected from implementing the draft regulation but does not include a potential second tier.

The minimum efficacy performance limits selected for the first tier will allow the continued use of the following:

- CFLi
- CFLn
- LFL
- IRC/xenon halogen
- LV halogen
- LEDs and other solid state lighting

As with other economies it is assumed that consumers will opt for replacement technologies with compatible lamp bases in the short-term with only marginal migration to other socket types over time. Accordingly the assumptions made in this analysis on the post Tier 1 regulatory lamp market shares for GLS and other GLS type lamps replacements are as follows:

- CFLi: 60% of the non-solid state GLS replacement market.
- Xenon/IRC halogen lamps: 40% of the non-solid state GLS replacement market.

For lower wattage incandescent lamps subject to the regulations it is assumed that replacements are as follows:

- CFLi: 50% of the non-solid state GLS replacement market.
- Xenon/IRC halogen lamps: 50% of the non-solid state GLS replacement market.

Solid state lighting is assumed to gradually take market share from all types of traditional screw-based lamps but beginning first with directional light sources such as halogen reflector lamps and GLS-R lamps. The share of new screw-based lamp socket hour sales taken by SSL reaches 9% by 2020 and 41% by 2030.

Japan

Although the regulations were not published at the time the analysis was done the phase-out schedule, policy intent and proposed industry response were known. Under this it is simply assumed that 70% of current GLS sales are replaced by CFLi post 2012 and that the remaining lamps are of small, decorative or speciality type. As with other economies solid state lighting is assumed to gradually take market share from all types of traditional screw-based lamps but beginning first with directional light sources such as halogen reflector lamps and GLS-R lamps. The share of new screw-based lamp socket hour sales taken by SSL reaches 9% by 2020 and 41% by 2030.

United States

While the US EISA regulations are clear in phasing-out traditional GLS at traditional power levels (100 W, 75 W, 60 W and 40 W) they leave a fair degree of latitude regarding the choice of replacement lamps and hence there is uncertainty about the eventual market response. The regulations are expressed in terms of wattage limits per lumen range or bin. This means at the higher light level end of each range the efficacy of replacement lamps has to be significantly greater than at the lower end of the range, Figure 5.1.

Current lamps that can satisfy these requirements include:

- Xenon halogen lamps
- Xenon halogen lamps with modified spectrum
- CFLi and CFLn
- LEDs

The intention of the regulation is a phased replacement between 2012 and 2014 of:

- 100 W by 72 W or lower power lamps
- 75 W by 53 W or lower power lamps
- 60 W by 43 W or lower power lamps
- 40 W GLS by 29 W or lower power lamps

Were the replacements to be like-for-like in luminous flux to the traditional GLS lamps this would result in average power savings of at least 28%. However, the stringency of the regulations in terms of efficacy is lower at the bottom end of each lumen bin than at the top by an average of 7 LPW. This implies that were a cheap lamp technology to become available that could just satisfy the requirements at the lower end of each lumen bin it could gain market share among consumers who are reluctant to pay the price of higher efficiency lamps designed to provide the traditional light levels. Furthermore instead of purchasing the low light output version of the GLS replacement lamp consumers could move up a power class and purchase a lamp at the lower light output range of the next wattage group. The authors are not aware of any such lamp currently on the market but as the efficacy requirements for modified spectrum lamps are significantly lower than for standard GLS lamps there may be an opportunity to find a low cost adaptation of these lamps that would meet the letter of the law if not the spirit. Modified spectrum lamps are currently retailing for prices that are only slightly higher than GLS lamps.

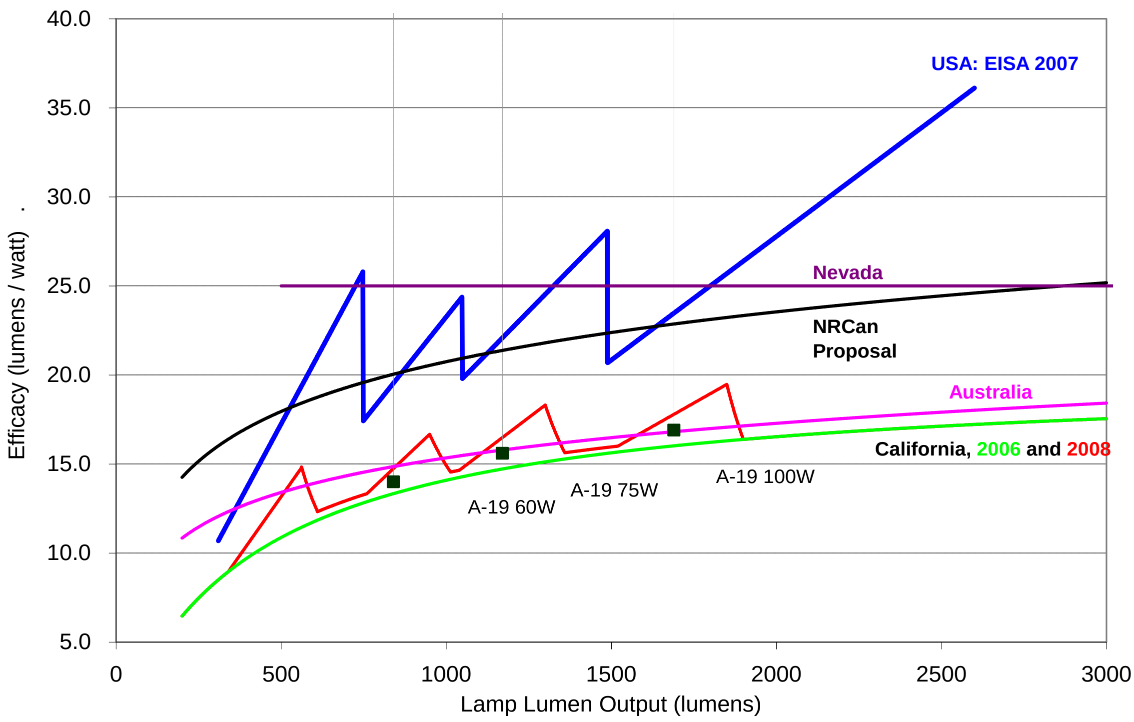
Accordingly the assumptions made in this analysis on the post Tier 1 regulatory lamp market shares are as follows:

- CFLi: 60% of the non-solid state GLS replacement market.
- Xenon halogen lamps: 20% of the non-solid state GLS replacement market.
- Improved Modified Spectrum lamps: 20% of the non-solid state GLS replacement market.

Beyond 2020 where the EISA tier-2 regulations require at least 45 LPW the following shares are assumed:

- CFLi: 100% of the non-solid state GLS replacement market.

Figure 5.1. Efficacy versus luminous flux requirements for Australian, Canadian and US regulations normalised to a common input voltage



Source: ECOS Consulting.

Solid state lighting is assumed to gradually take market share from all types of traditional screw-based lamps but beginning first with directional light sources such as halogen reflector lamps and GLS-R lamps. The share of new screw-based lamp socket hour sales taken by SSL reaches 9% by 2020 and 41% by 2030.

The rationale for the above market allocation assumptions is the assumed split in consumer preferences between consumers who are:

- Cost as opposed to life cycle cost conscious.
- Environmentally motivated versus otherwise.
- Take into account the different light quality and performance characteristics of the lamps in relation to the sensitivity of specific lamp socket types to light quality issues.

It is assumed that CFLi will be available that meet all but the most exacting performance needs (*i.e.*, maximum CRI) but that these lamps may incur a modest price premium compared with standard CFLi.

Europe

For the EU and IEA European economies draft regulations had not been prepared at the time the analysis was first conducted. Accordingly it was assumed that all EU and IEA European economies adopt harmonised requirements and that multiple scenarios were possible. For this report the DG-TREN Option 1 Fast and DG-TREN Option 1 Slow scenarios are considered. These are the most ambitious scenarios in terms of stringency and hence the ones which would have the greatest impact on the international market for CFLi. The lamp types which are permitted under these scenarios are shown in Tables 3.4 and 3.5. The assumptions made in this analysis on the post regulatory lamp market shares are largely the same for both scenarios with the main difference being that the timing varies. In the Fast option only CFLi and high performance LEDs are permitted from the outset. In the Slow option there is a window up to 2017 where the most efficient types of new halogen could be used as substitutes for regulated lamps but the main distinction is that the timing of the phase-out for certain classes of incandescent and halogen lamp is delayed compared with the Fast option. For GLS and halogen lamp replacements under this scenario the following replacement shares are assumed:

- CFLi: 90% of the non-solid state GLS replacement market rising to 100% by 2017.
- IRC/LV Xenon halogen lamps: 10% of the non-solid state GLS replacement market dropping to 0% in 2017.

Solid state lighting is assumed to gradually take market share from all types of traditional screw-based lamps but beginning first with directional light sources such as halogen reflector lamps and GLS-R lamps. The share of new screw-based lamp socket hour sales taken by SSL reaches 9% by 2020 and 41% by 2030.

China and other regions

China is the dominant county in the international lamp market having the largest sales volumes and the largest industry in terms of volume. Even though China has not formally adopted a phase-out policy such a policy is under firm consideration and it was therefore considered to be essential to analyse how potential future phase-out regulations in China might influence the global demand for lamps. Two scenarios are considered:

- GLS phase-out between 2012 and 2014
- GLS phase-out from 2013 to 2017

As China is the home of the CFLi industry and screw-base lamp technologies are dominated by GLS or CFLi in the domestic market the scenarios consider simple GLS replacement by CFLi. More sophisticated options may be investigated in future scenarios.

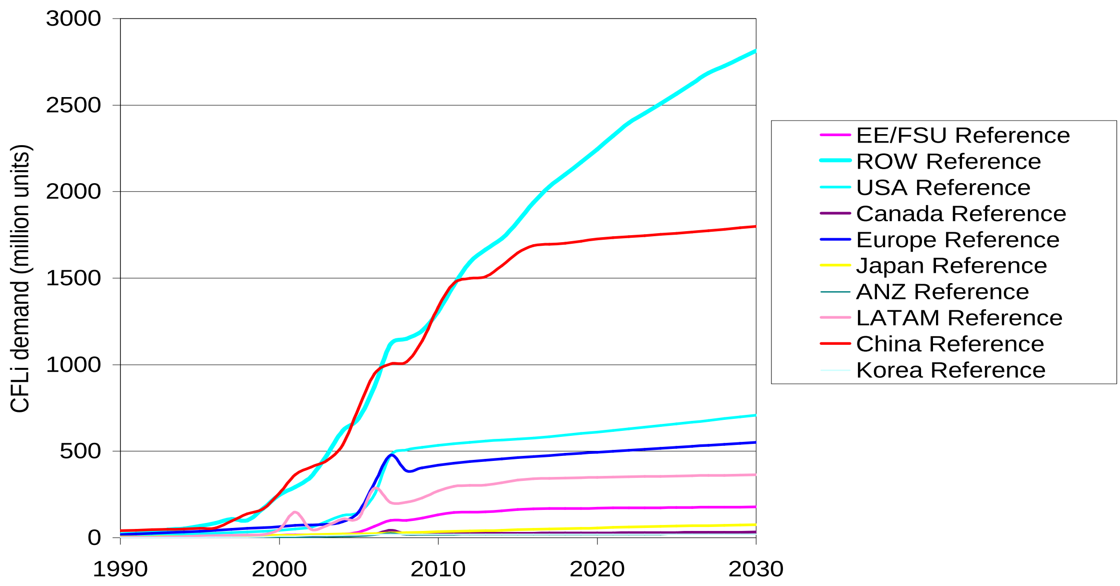
In the rest of the world individual national phase-out policies were not analysed but instead were taken into consideration in the development of a reference case scenario for the Rest of the World. This scenario aims to take account of the increased demand already being seen from phase-out activities underway in Latin America and Thailand and to add to that a slight increase in prevalent CFLi demand in response to the pending initiatives in countries such as the Philippines, Argentina, Columbia, Tunisia and potentially Brazil. It does not quantify these impacts carefully however, nor is demand for lamps other than CFLi and GLS considered.

5.2. Phase-out scenario results

Reference case scenario

Under the reference scenario, wherein it is assumed that no energy efficiency regulatory policies applicable to household lamps are adopted, demand for CFLi is set to expand dramatically despite many economies "applying the break" to future sales growth. In Australia, New Zealand, the EU and the United States continued sales of CFLi at 2007 levels would lead to the eradication of most of the GLS market. In Japan and Korea the decline in GLS sales associated with static 2007 level CFLi sales would be less pronounced but in these countries the GLS market is already comparatively small. Accordingly it is assumed in the base case scenario for most OECD countries that there is a decline in CFL sales in 2008 back towards the 2003 to 2006 trend. After this period sales do resume growth but at a more modest pace. Even under these conservative assumptions, GLS sales decline sharply in all IEA countries to a small fraction of the level they held in 2007. It should be noted that provisional data on the European CFL market for the first months of 2008 within the Eurostat Prodcom database, continues to show increasing demand, which suggests that the assumption of a temporary decline in OECD CFLi sales may be overly conservative. Conversely it is difficult to know how much willingness there is among the population at large to make a wholesale switch from GLS to CFLi without a regulatory push. The recent rising CFLi sales trends may be the result of the collective purchase decisions of a large section of the population, but there may be a sizable minority that is unwilling to countenance using CFLi, which could effectively set an upper bound on the size of the residential CFLi market. No such boundary is assumed here; largely because if it exists its magnitude is unknowable and because recent CFLi sales are of such a magnitude that they imply a wholesale shift in consumer preferences. It should be noted that while the Reference Case scenarios shown here forecast continuing strong growth in CFLi sales they follow a similar direction to the base case projections made by Philips in their screw-base lamp market analyses but attain a slightly higher absolute total because of a higher assumed global lamp socket growth but also because of more pessimistic assumptions about the rate of penetration of SSL.

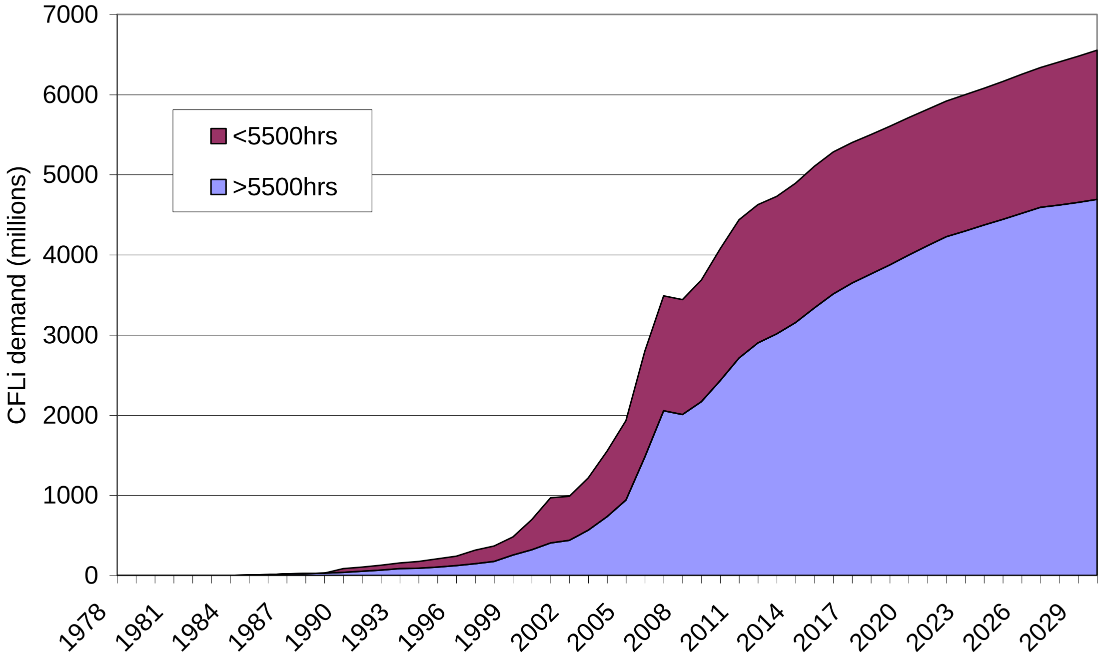
Figure 5.2. Reference case projections of CFLi sales demand



Source: IEA estimated.

Figure 5.3 shows global aggregate CFLi sales in the Reference Scenario differentiated by lamp life. Under this scenario there is a continuation of the sustained growth in global CFLi sales but 2007 is not only the point of inflection but also followed by a small and temporary reset in sales much as occurred in 2002 but to a more acute degree. There are small undulations in the otherwise smooth trend in future sales growth, which are associated with replacement CFLi sales in response to previous larger sales fluctuations. The volume of shorter life CFLi sales increases much less rapidly than for the slightly longer life products but there is still a continuing market for very cheap low-quality lamps in the non-OECD markets. Demand for longer life CFLi begins to plateau around 2030 and all CFLi sales are approaching saturation at around 7 billion lamps per year sometime post 2030.

Figure 5.3. Projected growth in global CFLi sales under the Reference Case Scenario



Source: IEA estimated.

It should be noted that this Reference Scenario will not come to pass for the economies that are already committed to phase-out GLS. For these economies the phase-out scenarios presented in the next section are the best indicator of future demand. Nonetheless the Reference Scenario is instructive in providing some indication of where international markets seemed to be heading prior to regulations entering into force.

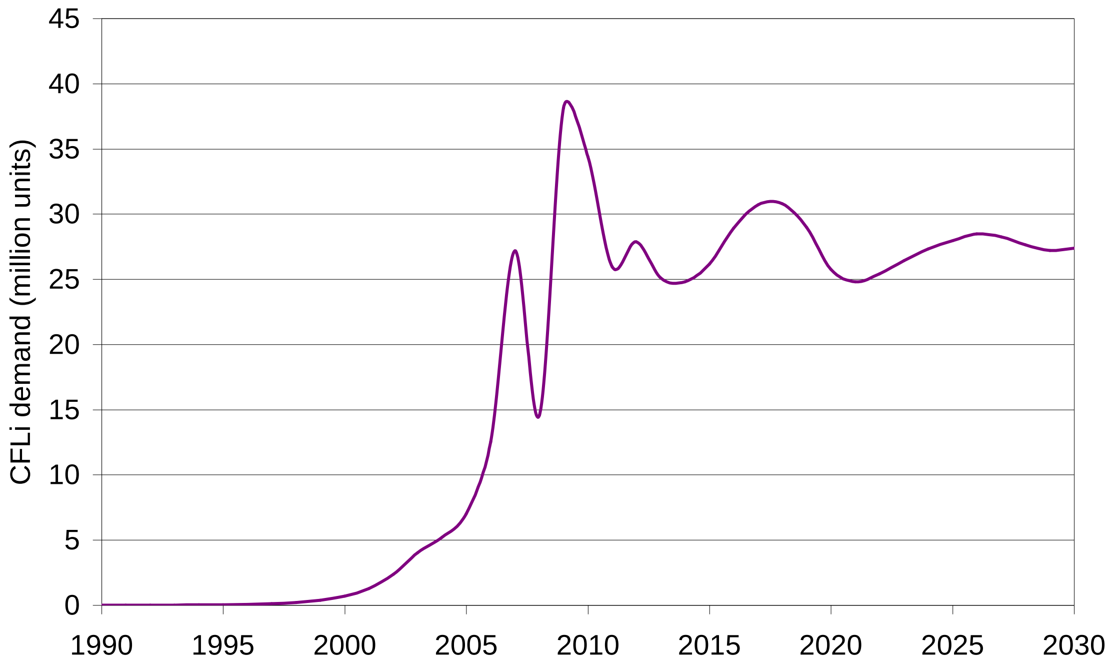
Projected CFLi demand in response to phase-out regulations

Australia and New Zealand

CFLi sales rose so sharply in Australia and New Zealand in 2007 to around 27 million lamps that they would not need to increase further to meet the phase-out requirements. In the Reference Scenario it is assumed this was a blip and that sales decline again in 2008 before the first stages of the regulations start to take effect in 2008, but this assumption could be misleading and it is just as possible that pre-emptive stock-building is occurring. Under the case shown here sales rise sharply in 2009 and again in 2010 to reach a peak of just under 40 million lamps, as the large majority of GLS classes are phased-out. Almost immediately afterwards, however, sales drop back to around 2007 levels and oscillate at about 27 million lamps for the rest of the scenario. A second, but significantly less pronounced, sales rise would be expected were more stringent second tier regulations to be implemented that prohibit current halogen alternatives.

Although the Australian and New Zealand lamp market is small this scenario illustrates how demand for CFLi can show a sharp rise and fall in response to a rapid phase-out schedule.

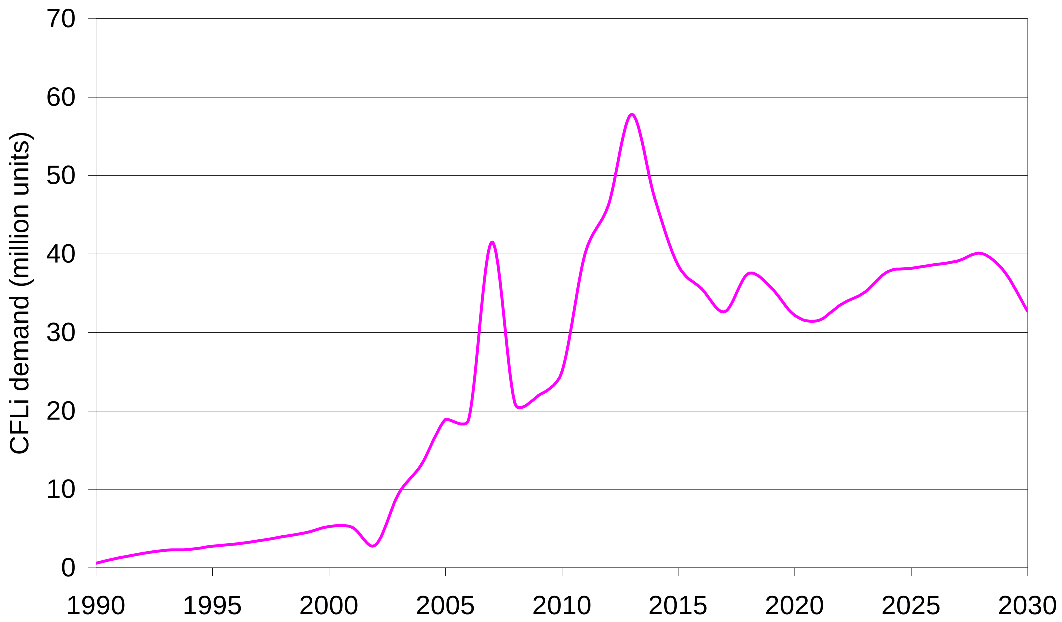
Figure 5.4. Projected CFLi sales in Australia and New Zealand in response to Tier 1 phase-out regulations in Australia



Source: IEA estimated.

Canada

Figure 5.5. Projected CFLi sales in Canada in response to Tier 1 phase-out regulations



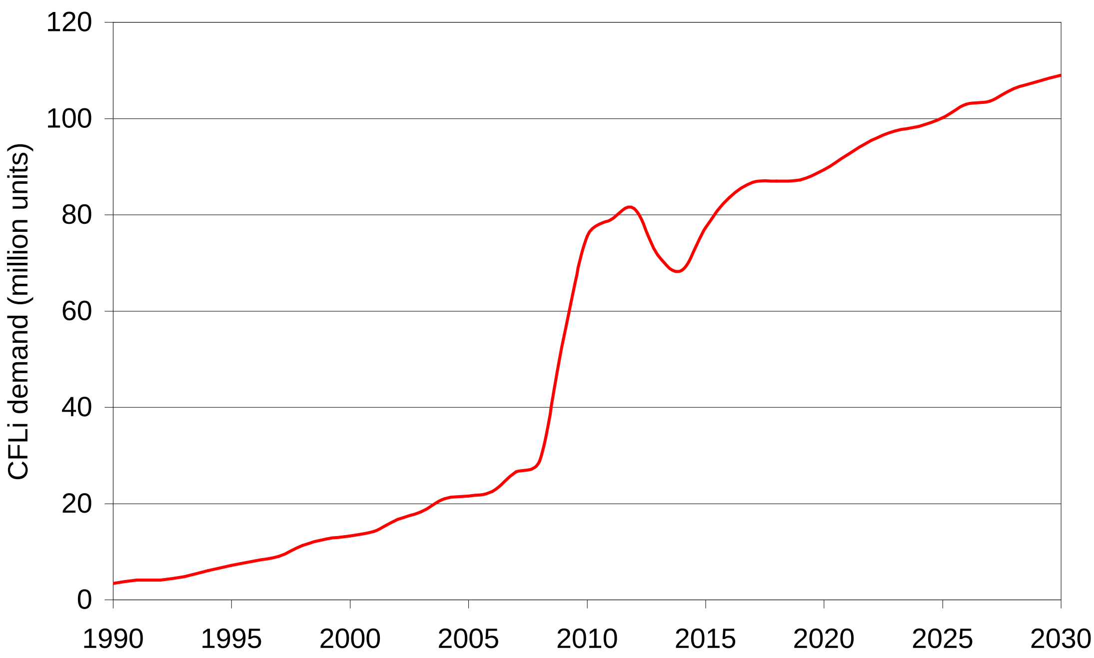
Source: IEA estimated.

In Canada, as in Australia and New Zealand, it is assumed that the sales peak in 2007 is followed by a sales decline before rising again to quite a sharp peak of just under 60 million CFLi in 2013. This is followed by a decline back to around 2007 sales levels. A second, but much less pronounced, sales rise would be expected were second tier regulations to be implemented. A strong note of caution should be added to this projection, however, as there is still some uncertainty about the actual CFLi sales trend in Canada up to and including 2007. Efforts are on-going to resolve this and should lead to a clearer understanding in the next stage of this research.

Japan

In Japan CFLi sales are projected to sharply increase their rate of growth and to peak at about 80 million lamps per year in 2012. This is followed by a sales decline of roughly 10 million CFLi in 2014 in response to a softer replacement market *i.e.*, as a direct consequence of the rapid change in sales in 2008, before resuming an upward growth curve as the stock of screw-base lamps continues to increase.

Figure 5.6. Projected CFLi sales in Japan in response to Tier 1 phase-out regulations

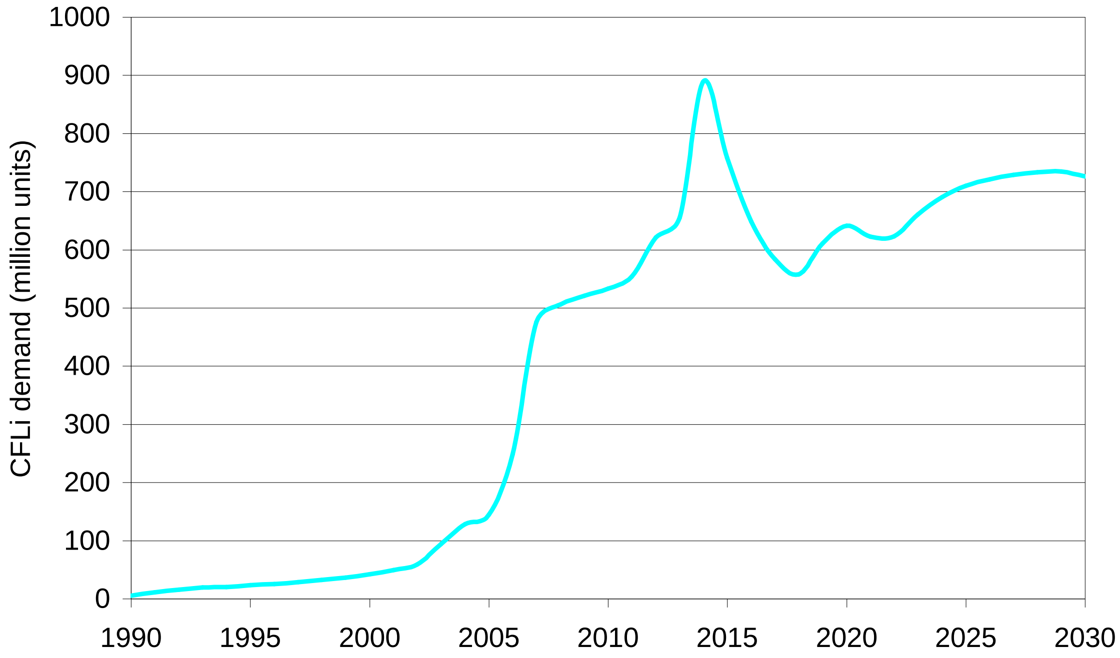


Source: IEA estimated.

The United States

In the United States the rate of CFLi sales growth is projected to decline sharply from 2008 to 2011 but still to lead to a considerable gain in screw-base lamp socket share. Despite this sales growth the EISA regulations result in a sharp rise in demand for CFLi from 2012 to 2015 peaking at just under 900 million lamps. This is followed by a sharp down-turn in demand about 560 million lamps in 2018. Thereafter the second tier regulations take effect but only require a modest increase in sales because a large proportion of the screw-base lamp stock is already converted to higher efficiency lamps and the intermediate xenon halogen options that are now being replaced have a longer lifetime and slower replacement cycle than the GLS they replaced. Sales continue to rise more modestly but show ongoing fluctuations as the replacement lamp market responds to the 2015 peak and trough. In addition solid state lighting begins to make accelerated inroads into the lighting market in the 2020 to 2030 timeframe at the expense of CFLi.

Figure 5.7. Projected CFLi sales in the United States in response to Tier 1 and Tier 2 phase-out regulations



Source: IEA estimated.

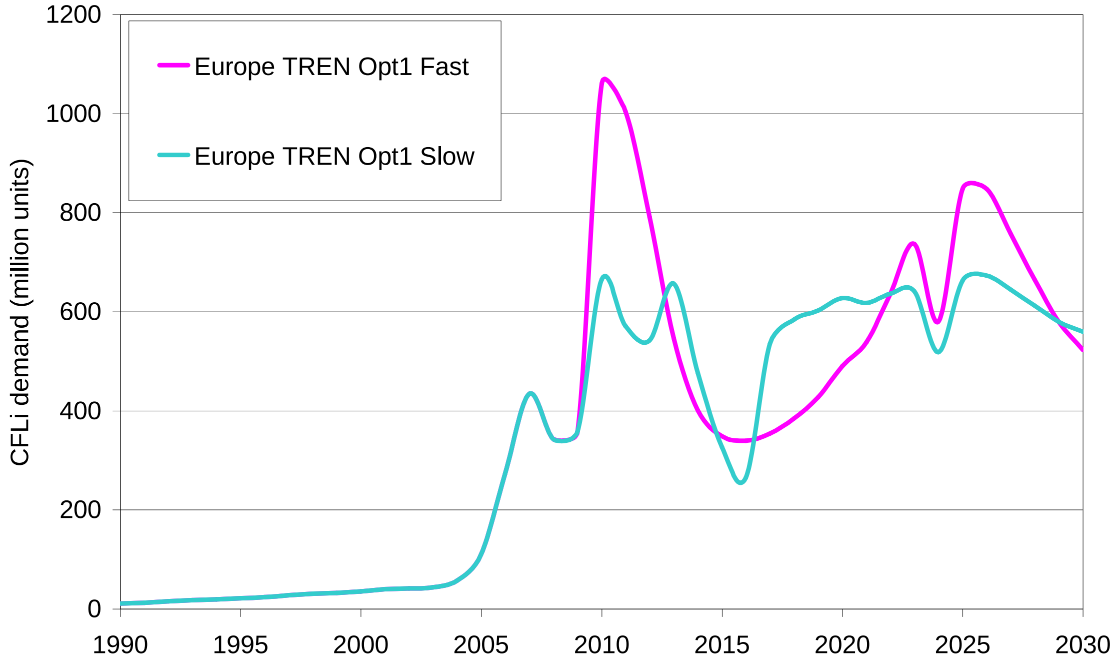
Europe (EU27, Switzerland and Norway)

The two stringent phase-out scenarios considered for the EU result in very different demand profiles for CFLi, Figure 5.8.

The Fast option results in a sharp rise to a peak in CFLi demand of just under 1.1 billion lamps in 2010 before an almost equally rapid decline to about 360 million lamps in 2016. Sales then rise to 750 million before a small dip and rise brings them to a second peak in 2026 of about 860 million lamps, before declining again. The tight regulatory window and high stringency of the scenario produces a strong initial peak and strong replacement cycle oscillations in the future.

As in most other OECD markets 2008 sales are presumed to decline slightly from 2007 levels in both the Option 1 Fast and Slow scenarios; however in the Slow case there is much more stability in the demand profile. There are peaks in 2010 and 2013 at about 650 million lamps followed by a sharp trough in 2016 at about 270 million lamps. Thereafter sales rise and fluctuate about the 600 million level.

Figure 5.8. Projected CFLi sales in the EU in response to Tier 1 and Tier 2 phase-out regulations



Source: IEA estimated.

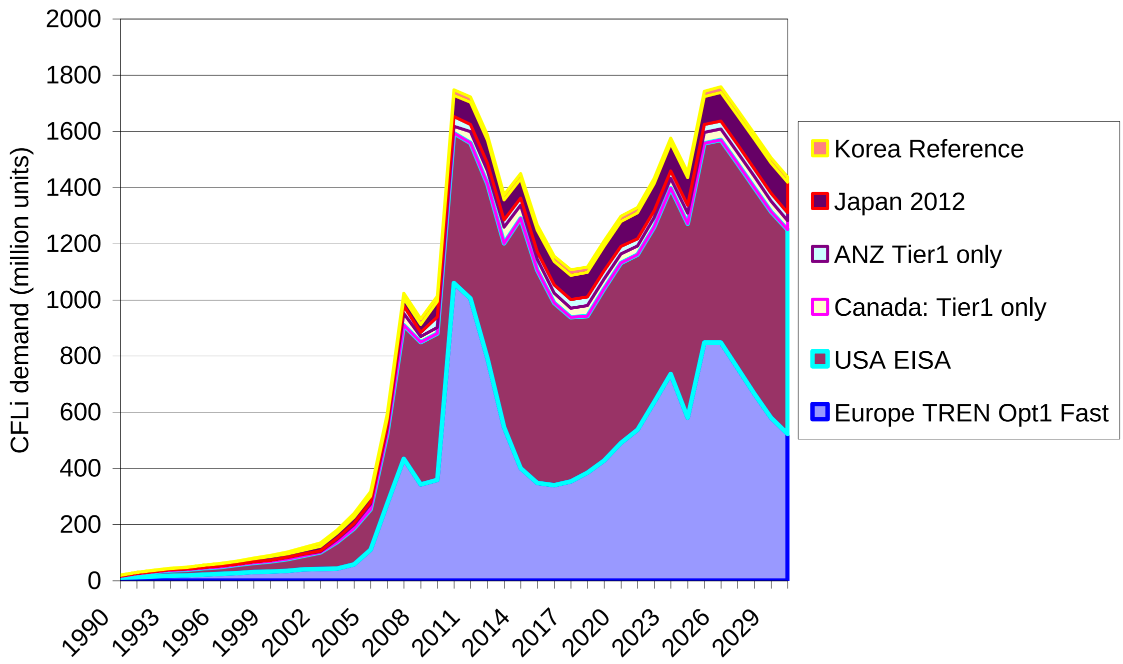
Collective OECD CFLi demand in response to phase-out requirements

The combined response of these regulations is shown in Figures 5.9 to 5.11 for both EU phase-out scenario cases and without the EU taken into account. The aggregate demand profile is dominated by the two large markets of the United States and the EU. If the EU Option 1 Fast scenario is included demand grows steeply to 1 750 million lamps in 2011, declines to 1 100 million lamps in 2018 and then returns to 1 750 million in 2026.

If the EU Option 1 Slow scenario is included the sales have a mini peak in 2010 at 1 350 million lamps, a major peak in 2014 at 1 530 million lamps, followed by a trough in 2016 and then rising sales to 2027 peaking at almost 1 600 million lamps. The overall demand profile is much more stable than with the Option 1 Fast scenario.

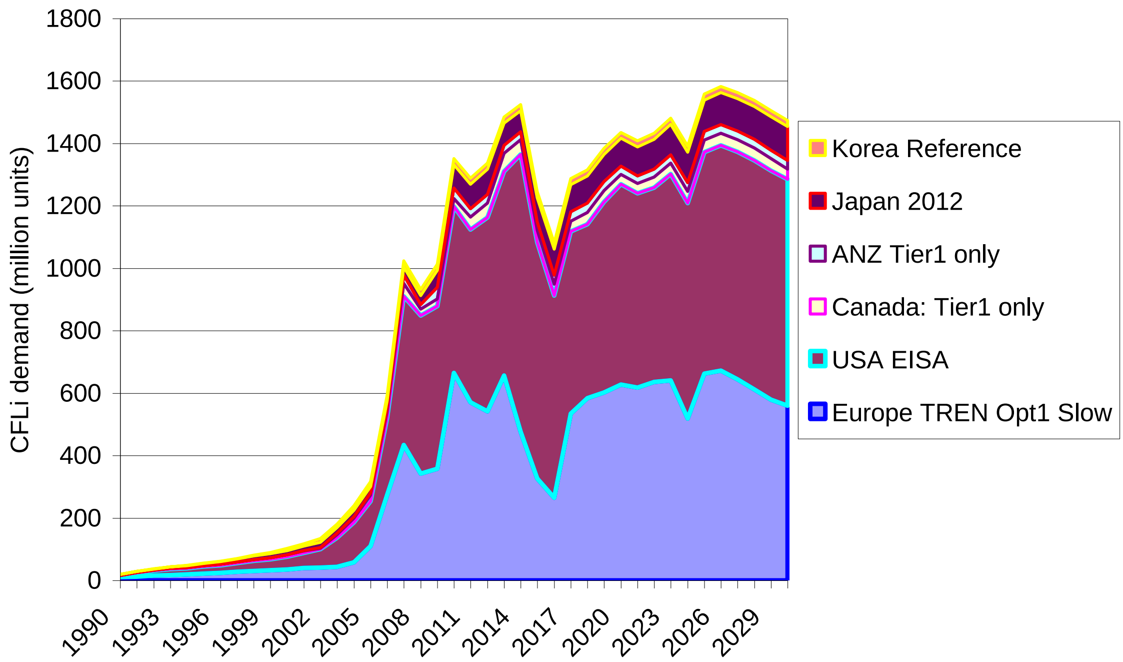
Discounting the EU altogether gives a demand profile dominated by the impact of the EISA regulations on the US market. Total CFLi demand peaks in 2014 at about 1 029 million lamps and troughs at about 713 million lamps in 2018.

Figure 5.9. Projected OECD CFLi sales in response to pending and potential GLS phase-out regulations



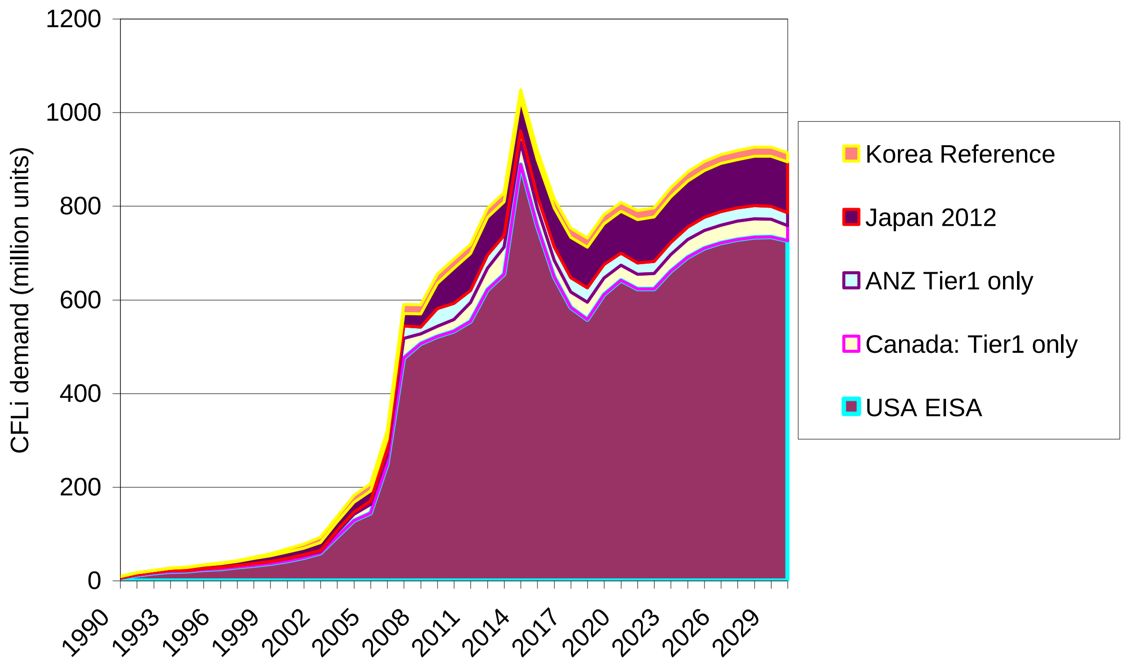
Source: IEA estimated.

Figure 5.10. Projected OECD CFLi sales in response to pending and potential GLS phase-out regulations



Source: IEA estimated.

Figure 5.11. Projected OECD CFLi sales in response to pending GLS phase-out regulations



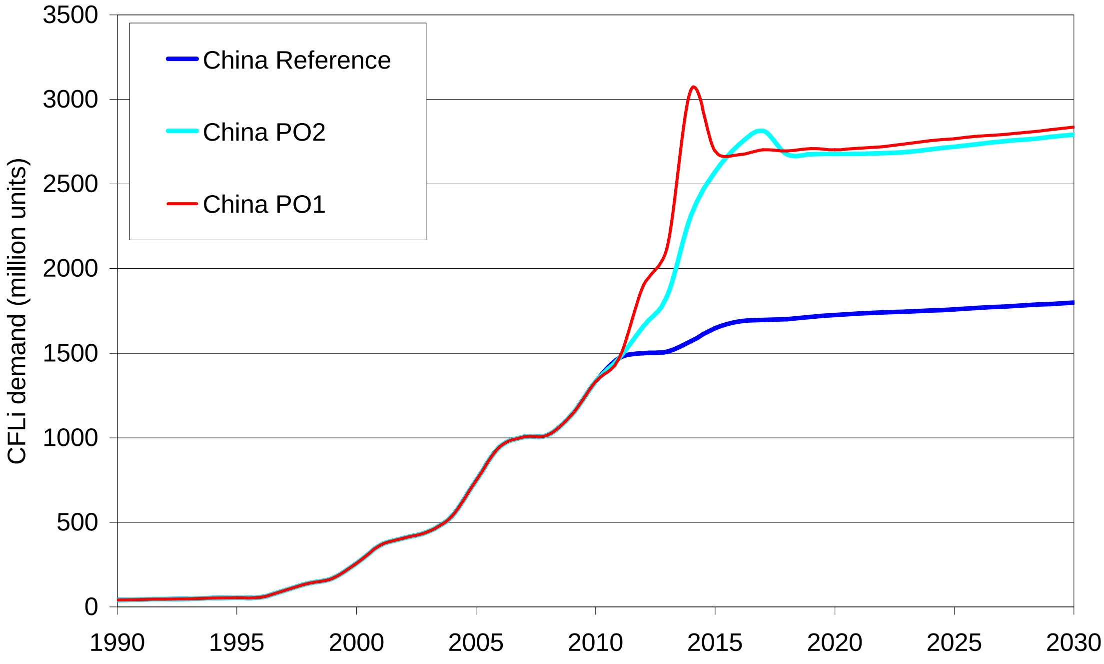
Source: IEA estimated.

The influence of China

Adding China into the picture makes a large difference as is shown in Figures 5.12 to 5.18. Under the reference case Chinese CFLi sales rise in an undulating manner to reach about 1.7 billion lamps in 2017 and grow at a steadier and more sedate pace. In the Phase Out 1 (PO1) case it is assumed that all GLS sales are phased-out from 2012 to 2014 while in the Phase Out 2 (PO2) case the timeframe is 2013 to 2017. Both result in final demand levels of almost 1 billion CFLi higher per year in the 2017 to 2030 timeframe. Under PO1 there is a sharp peak in demand at about 3.05 billion lamps in 2014 followed by a rapid drop in sales of about 300 million lamps. For PO2 the peak occurs later and the sales drop is only about 100 million lamps.

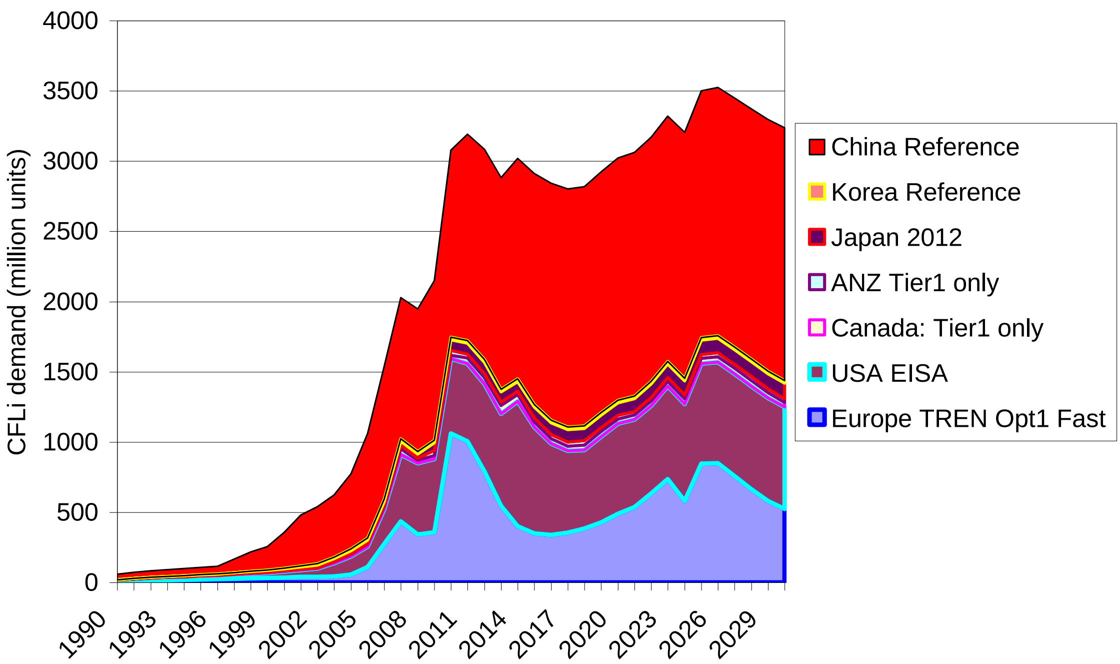
Superimposing these demand profiles on the OECD totals gives the outcomes shown in Figures 5.13 to 5.18.

Figure 5.12. Projected Chinese CFLi sales in response to hypothetical regulatory scenarios



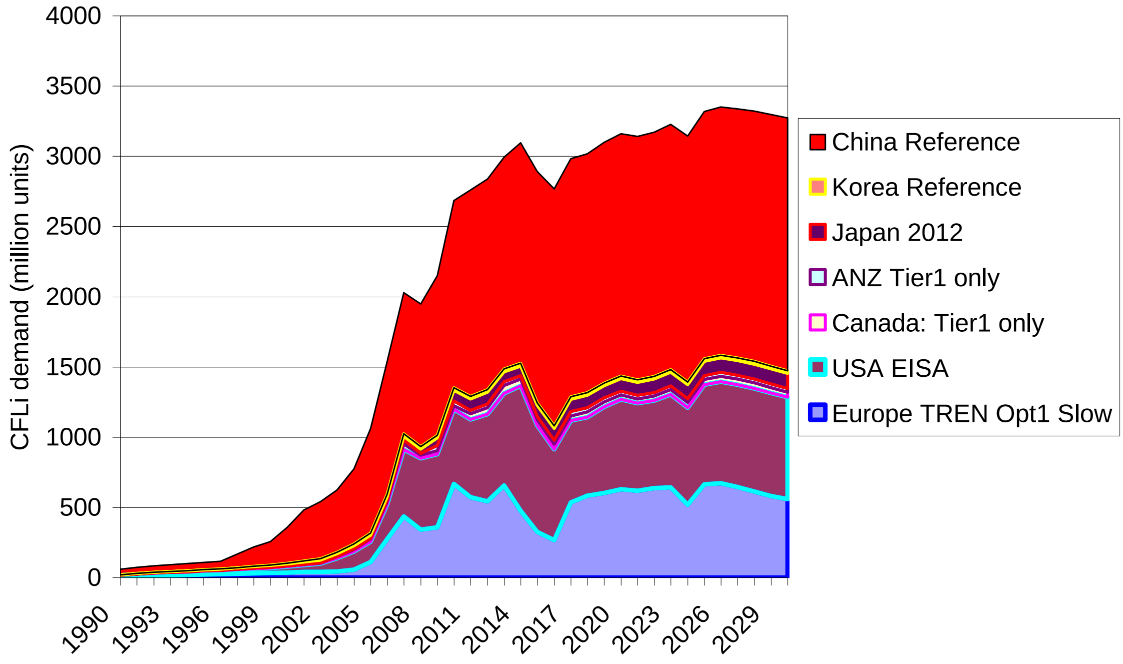
Source: IEA estimated.

Figure 5.13. Projected OECD and Chinese CFLi sales in response to pending and potential GLS phase-out regulations



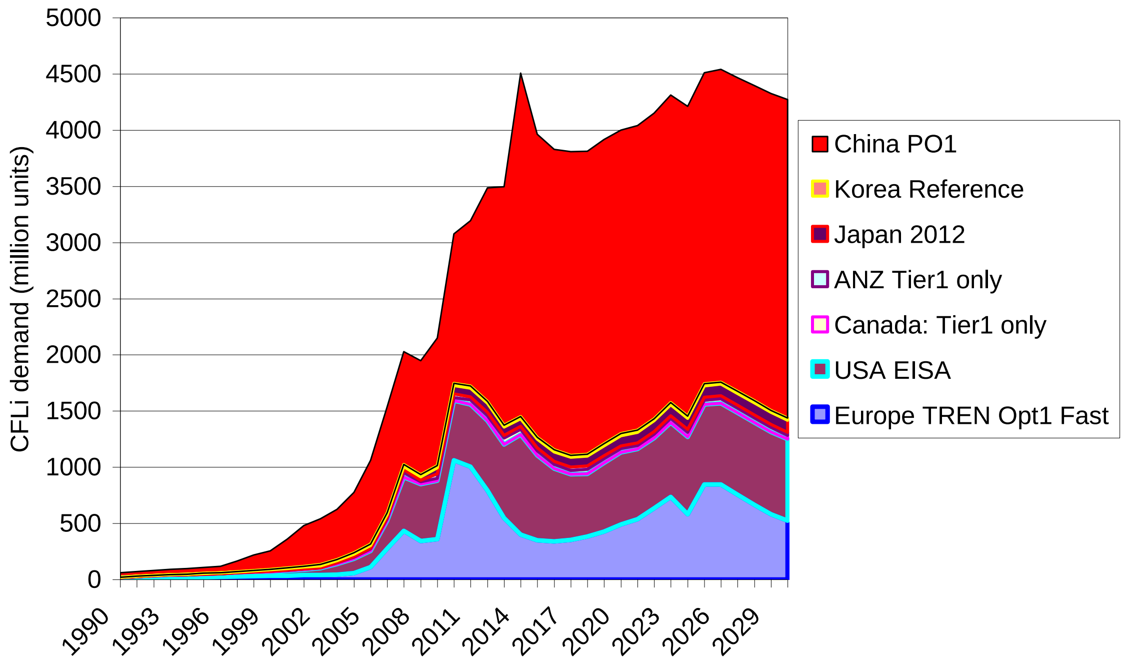
Source: IEA estimated.

Figure 5.14. Projected OECD and Chinese CFLi sales in response to pending and potential GLS phase-out regulations



Source: IEA estimated.

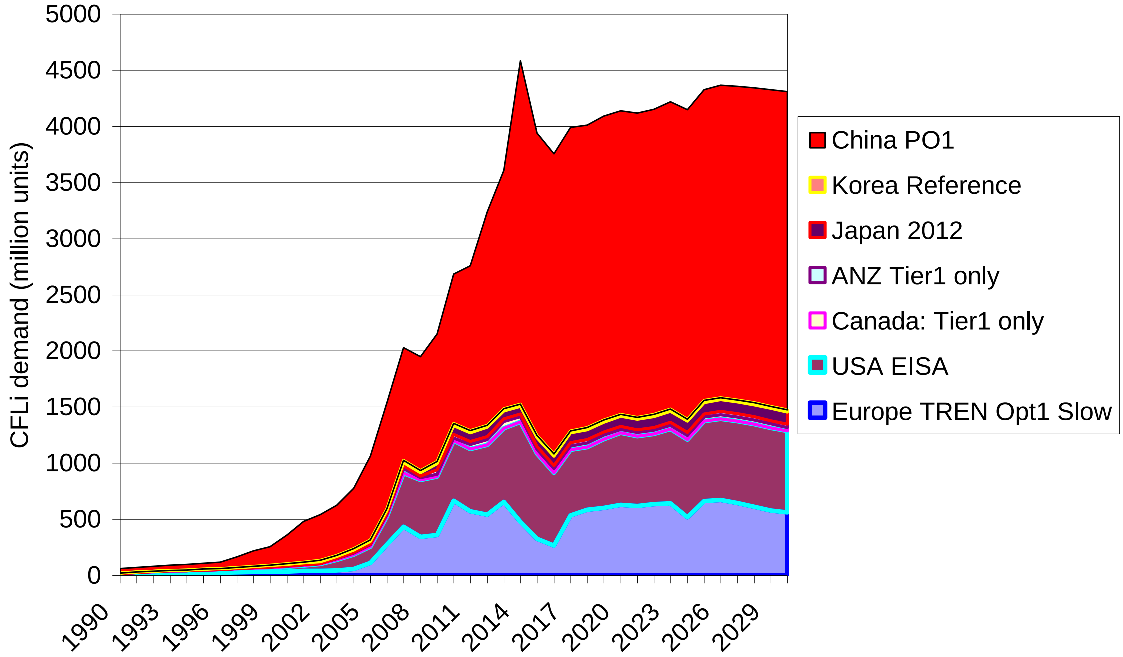
Figure 5.15. Projected OECD and Chinese CFLi sales in response to pending and potential GLS phase-out regulations



Source: IEA estimated.

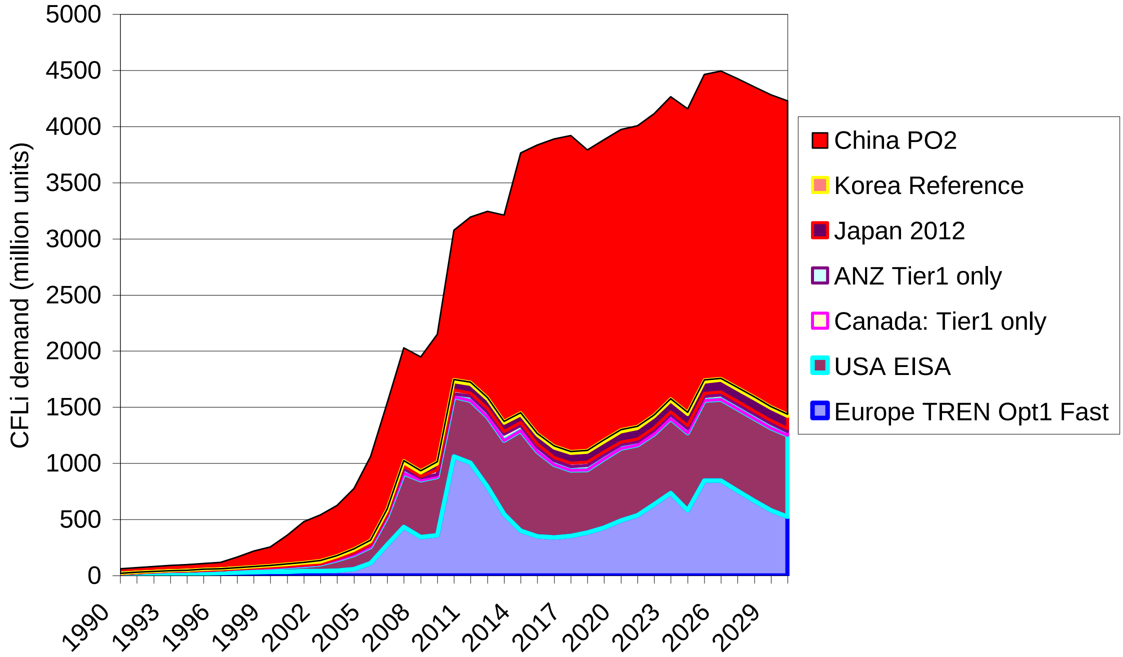
International Energy Agency

Figure 5.16. Projected OECD and Chinese CFLi sales in response to pending and potential GLS phase-out regulations



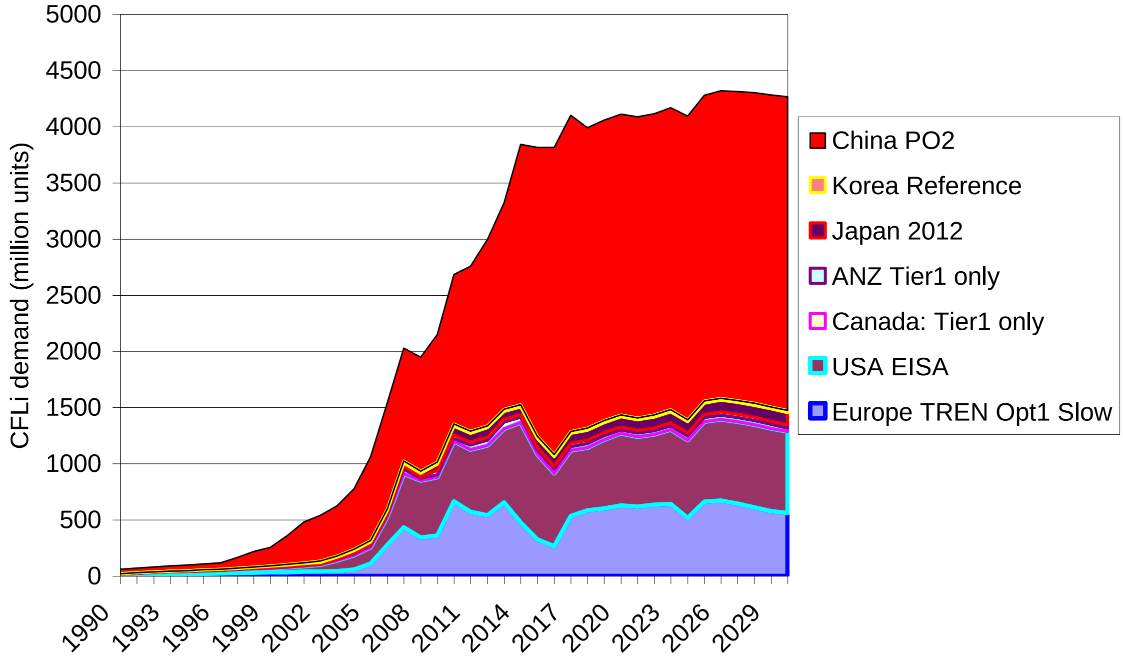
Source: IEA estimated.

Figure 5.17. Projected OECD and Chinese CFLi sales in response to pending and potential GLS phase-out regulations



Source: IEA estimated.

Figure 5.18. Projected OECD and Chinese CFLi sales in response to pending and potential GLS phase-out regulations



Source: IEA estimated.

6. Implications for the security of global lamp supply

This study has set out to quantify demand for CFLi in response to regulatory measures to phase-out incandescent lamps and from that to determine the risks of potential lamp shortages. It set out to consider the risks of shortages induced by the following:

- Demand for regulatory-compliant lamps increasing too rapidly for the industry and supply chain to be able to satisfy it.
- Additional demand might be short-lived and therefore industry would have little economic incentive to invest in the necessary production facilities required to meet the peak demand

These risks are now assessed in the light of the demand projections of Section 5 and based upon market and industrial information gathered for the study.

6.1. The risk of overly rapid growth in CFLi demand

To assess this risk the scenarios presented in Section 5 are complemented by adding Reference Case projections for demand in Latin America, the Former Soviet Union and the Rest of the World. Six variants are considered and shown in Figures 6.1 to 6.6:

1. China Reference Case, EU – TREN Opt 1 Slow
2. China Reference Case, EU – TREN Option 1 Fast
3. China PO1 (Phase-out 2012-14), EU – TREN Option 1 Slow
4. China PO1 (Phase-out 2012-14), EU – TREN Option 1 Fast
5. China PO2 (Phase-out 2013-17), EU – TREN Option 1 Slow
6. China PO2 (Phase-out 2013-17), EU – TREN Option 1 Fast

Based on these demand profiles it is apparent that:

- Demand continues to grow strongly in all the scenarios reaching between 5.8 billion and 6.9 billion lamps by 2020 and 6.7 billion and 7.7 billion lamps by 2030.
- The fastest annual demand growth rate, of 1 094 million lamps, occurs between 2009 and 2010 for Scenarios 2, 4 and 6, *i.e.*, for those with EU-TREN Option1 Fast scenario included. Almost similar maximum annual demand growth rates of 1 054 million and 1 058 million lamps occur in 2013 to 2014 for Scenarios 3 and 4 (*i.e.*, those with Chinese phase-out from 2012 to 2014). At no other points do the annual lamp demand growth rates exceed the maximum historical increase of 866 million lamps, which occurred between 2005 and 2006.
- Under the highest demand case, which requires just above a doubling of global production by 2030, the rate of growth in demand is no greater than the industry has already achieved historically.

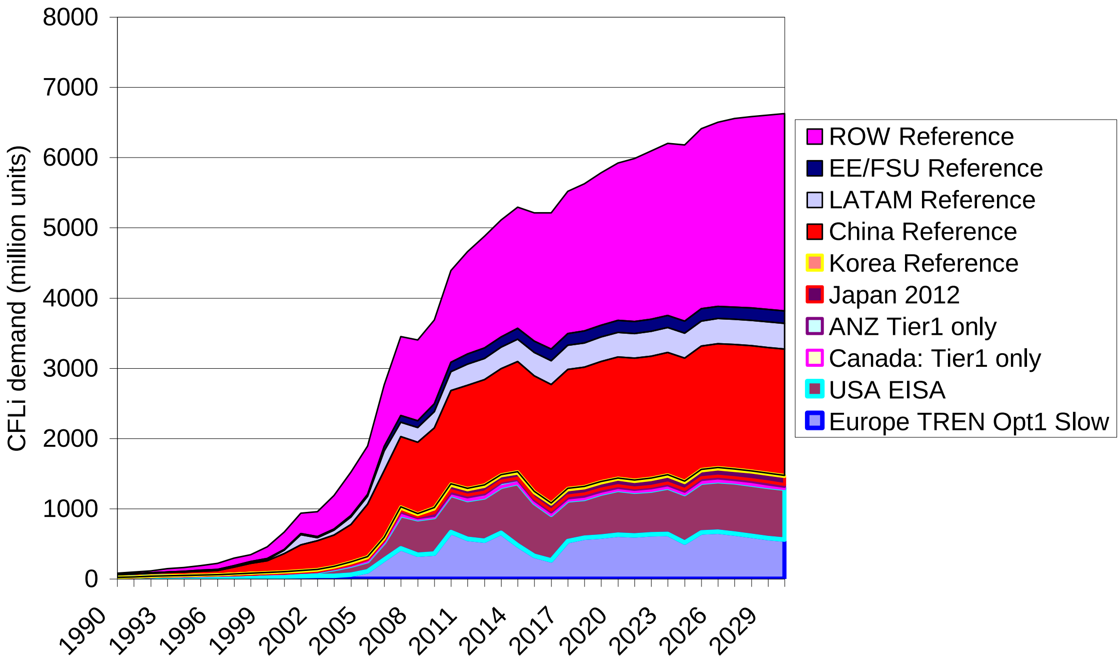
Following the logic that what has been done before could be done again, there does not seem to be a significant risk of industry not being able to meet the rate of demand growth with the possible exception of the cases with the most rapid phase-out schedules in the EU and in China. The high annual growth rate between 2009 and 2010 associated with the EU TREN Option 1 Fast scenario may also partially be an artefact of the assumption that sales decline slightly in 2008 before rising again thereafter. If the annual sales demand growth is averaged across 2008 to 2010 it becomes a more modest 445 million per year. The sharp growth assumed with China PO1 scenario is more robust, however, is also further ahead and hence would permit better planning.

The assumption that past growth rates can be repeated in the future may not hold true, however, if there are any bottlenecks building-up in component or material supply. It could also be invalid were the demand growth planning, which has previously allowed the industry to successfully add capacity up to 2007 to be in need of a pause due to other organisational constraints in the sector.

To try and gauge the extent to which these factors might be a problem, an informal survey was undertaken of industry professionals among diverse industry players, both within the big global lighting companies and among dedicated Chinese based CFLi manufacturers in China. The survey has not revealed any insurmountable bottlenecks of this type although it has revealed considerable organisational and planning challenges. In the case of Chinese-based suppliers some expressed considerable confidence that they can scale-up production to meet demand providing they have reasonable demand forecasts. Greater concerns were evident among the large international companies but mostly concerning the scale of the organisational challenge that needs to be addressed.

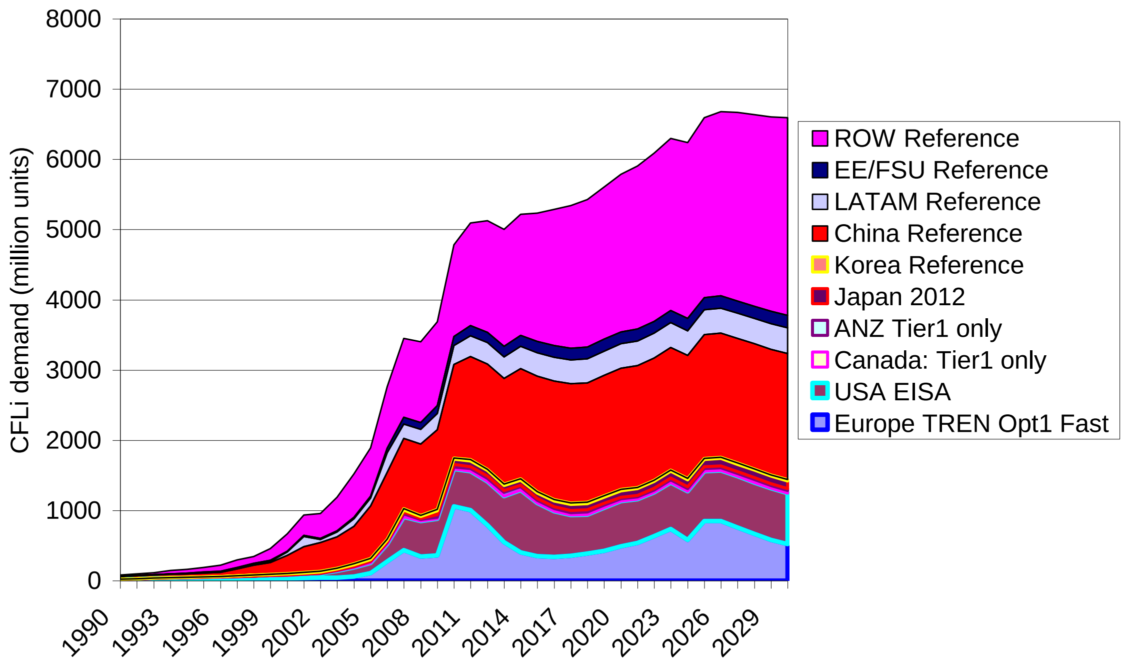
Concerns have been greater with respect to high-quality CFLi as will be discussed later.

Figure 6.1. Global CFLi demand variant 1)



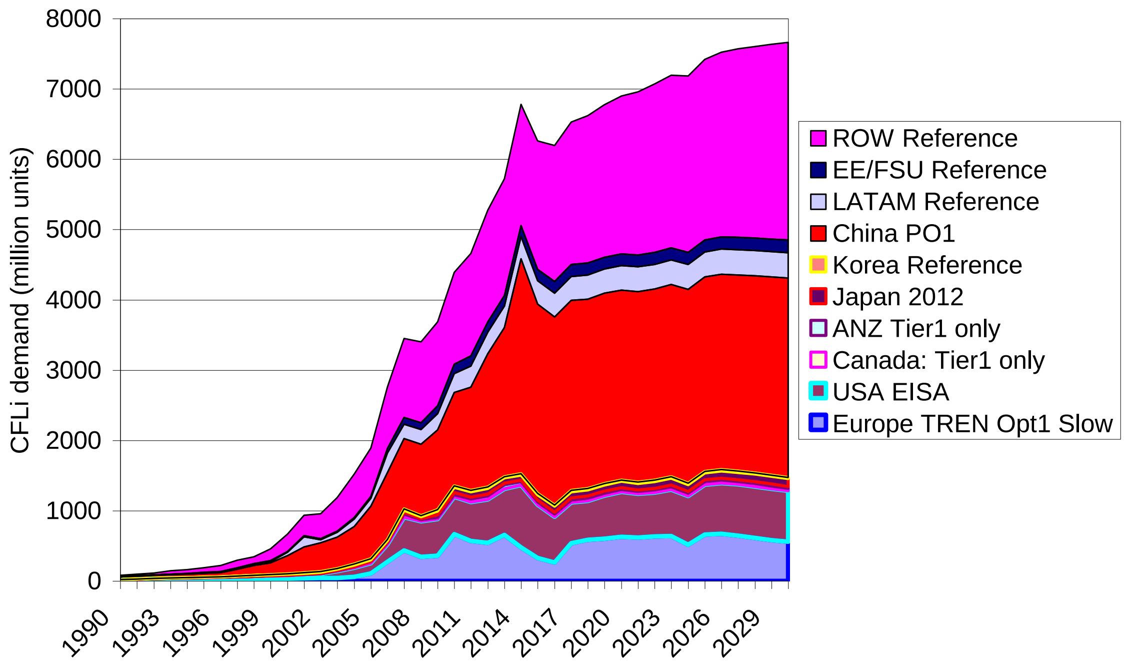
Source: IEA estimated.

Figure 6.2. Global CFLi demand variant 2)



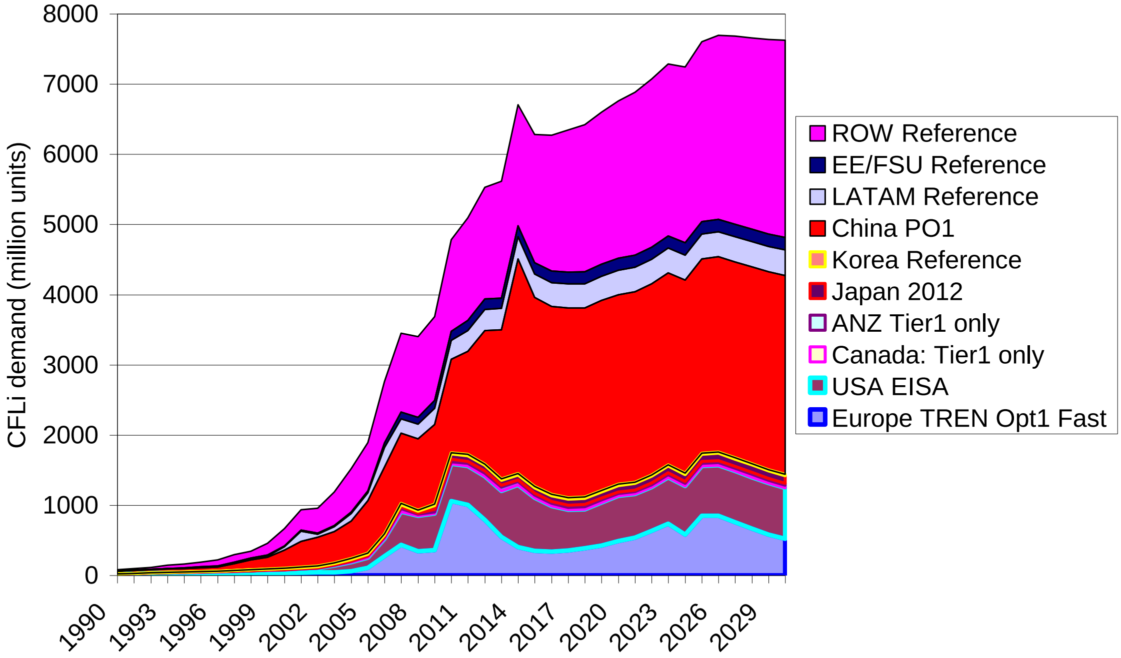
Source: IEA estimated.

Figure 6.3. Global CFLi demand variant 3)



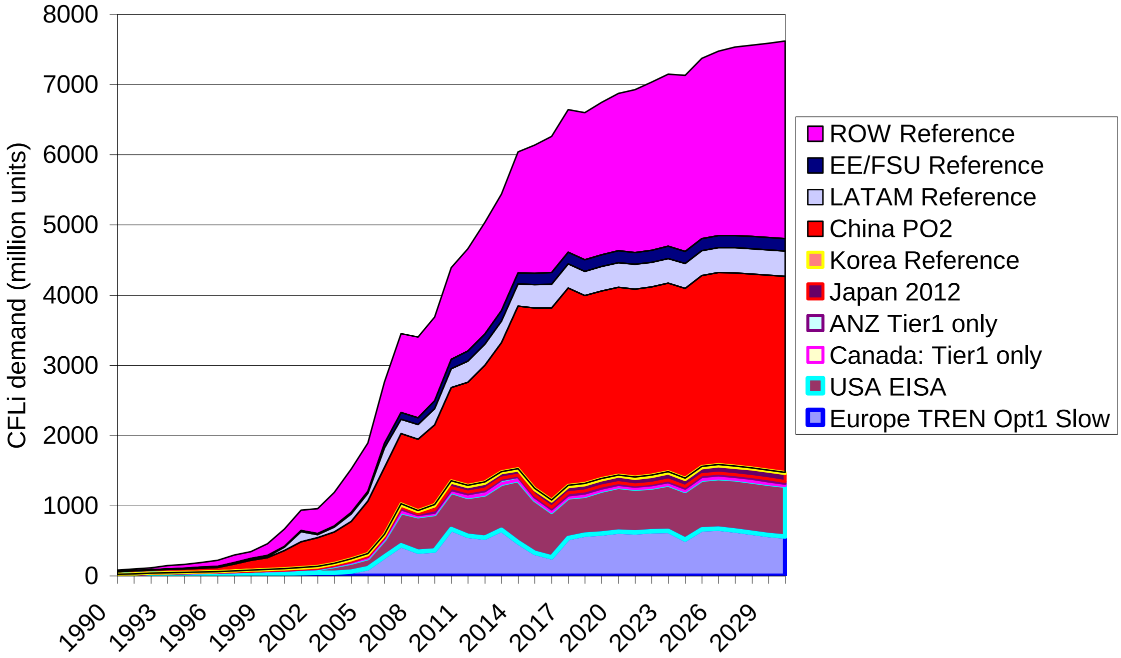
Source: IEA estimated.

Figure 6.4. Global CFLi demand variant 4)



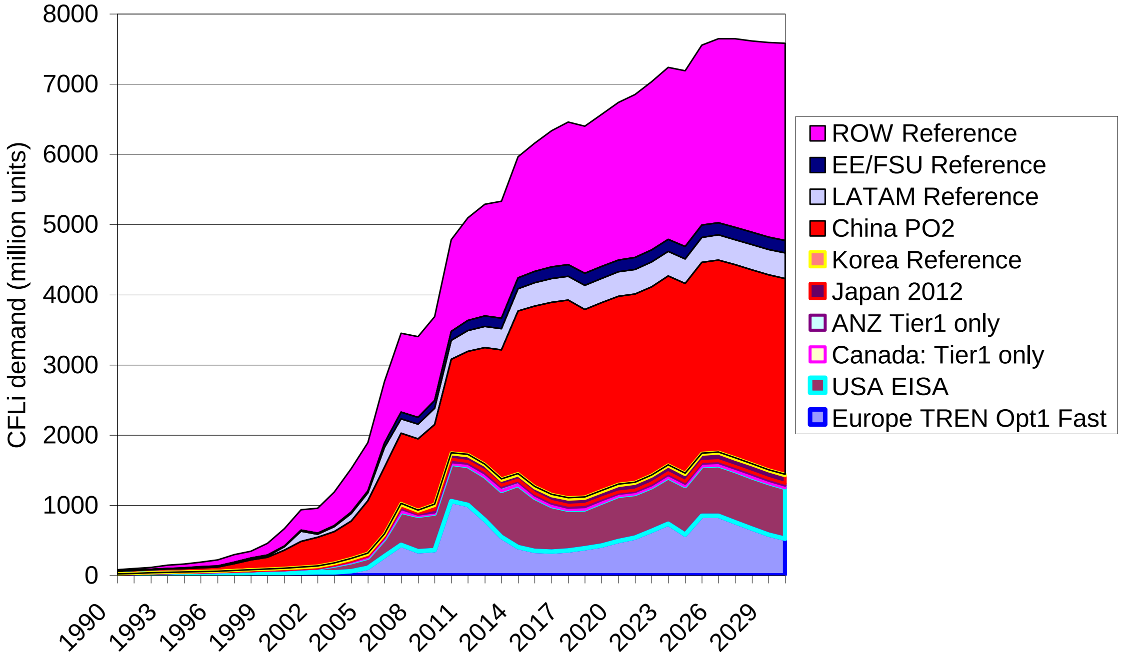
Source: IEA estimated.

Figure 6.5. Global CFLi demand variant 5)



Source: IEA estimated.

Figure 6.6. Global CFLi demand variant 6)



Source: IEA estimated.

6.2. The risk of stranded assets

As previously mentioned, short-lived spikes in demand present a risk that manufacturers would be disinclined to make the necessary investment in CFLi production due to legitimate concerns about being left with stranded assets. The analyses of global demand profiles for CFLi shown in Scenarios 1 to 6 above are instructive because they illustrate the magnitude of this risk.

Under Scenario 1 a short lived drop in sales occurs in the 2015 to 2016 timeframe but sales pick up again in 2017 so the drop-off could be managed by any affected producers by going slow. A similar but shorter lived sales drop occurs in Scenario 2 in 2013. Both scenarios assume that China does not introduce regulatory measures to phase-out GLS.

Under Scenarios 5 and 6 there are very minor drops in 2018 and again in 2024 but these would be comfortably managed. Both scenarios do assume that GLS phase-out regulations are introduced in China but over a 2013 to 2017 timeframe.

For Scenarios 3 and 4, which both encompass Chinese phase-out activity between 2012 and 2014 there are significant sales declines of between 425 million and 525 million lamps in 2015. Important as these are they are short lived and sales growth resumes again in 2017.

Towards the end of all the scenarios CFLi sales undergo slow reductions that are attributable to competition from solid state lighting (although as mentioned before, competition could start earlier than is assumed here).

Considering these factors there appears to only be a limited risk of stranded assets attributable to phase-out regulatory activity for CFLi producers supplying a global market. This is because the peaks in demand driven by regulations are not in-step. Were they to be synchronised there is a much greater chance of demand spikes occurring. Nonetheless this analysis is predicated on the following assumptions:

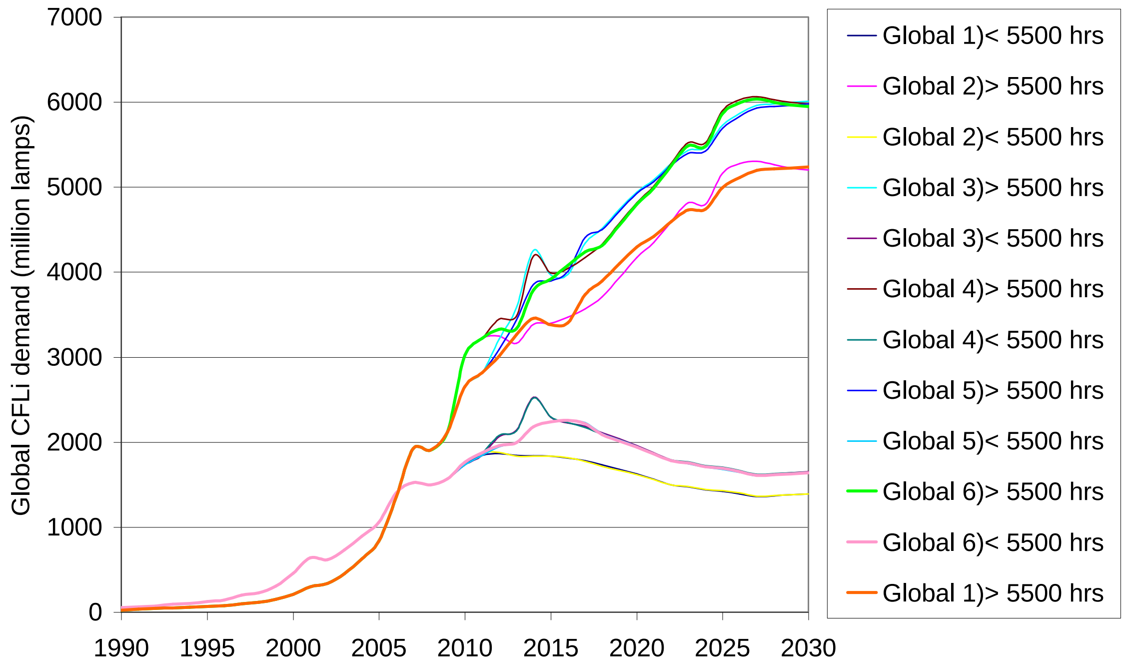
- Specific levels of baseline demand growth for screw-base lamp sockets in different markets.
- With the exception of China, none of the countries without a policy to phase-out incandescent lamps will go on to adopt one.

Neither of these assumptions may be correct and hence a greater number of scenarios will be looked at in the successor report to the present one.

6.3. The risk of low-quality lamps

A third possibility is that demand for lamp sales volumes may be met but that the quality of the available lamps will be insufficient to satisfy consumer expectations. Only a rather crude assessment of quality has been conducted here and this will be researched in more depth for the successor report. Figure 6.7 shows the assumed share of demand for lamps with life spans of more than 5 500 hours and those without under the six global demand scenarios presented in Figures 6.1 to 6.6. In all cases, it is assumed that demand grows faster for longer life lamps than lower life ones, which gradually lose market share. However, the rate of demand growth for longer-life lamps is generally slightly slower in the 2008 to 2012 timeframe than it was in the 2005 to 2007 timeframe, when OECD CFLi markets exhibited particularly strong growth. Of course the definition of quality being examined here is particularly simplistic and 5 500 hour life lamps will not satisfy pending quality provisions in many jurisdictions therefore only limited information can be drawn from this analysis. A more detailed analysis will be attempted in the successor report.

Figure 6.7. Demand for CFLi as a function of quality for six global demand scenarios



Source: IEA estimated.

7. Conclusions and future analyses

This analysis has helped to quantify the international demand for CFLi in response to regulatory measures to phase-out incandescent lamps. From this it is evident that demand for CFLi has been growing extremely rapidly in all markets over the last few years and that this is helping to dampen down the transitory effects that might otherwise have been expected from implementing the regulations. While there may yet be risks to the security of lamp supply from regulatory measures inducing sharply transient CFLi demand profiles, they appear to be relatively modest due to the following phenomena:

- The sharp rise in pre-regulatory sales of CFLi over from 2005 to 2007 that helps to both reduce future GLS replacement demand and to add industrial production capacity.
- The different regulatory measures are not being implemented in step and have diversity in their schedule and stringency.
- The emergence of new halogen technologies that will be permitted in some jurisdictions and help dampen the acuteness of CFLi demand increases.

Despite these encouraging findings, uncertainty remains regarding many aspects of the international developments that will benefit from further investigation. There are several areas where this analysis would benefit from strengthening and these could be explored in future studies. They include:

- Detailed energy and CO_2 impacts.
- Additional scenarios to address:
- Pending and potential regulations or other policy stimuli in China and other major non-OECD economies such as India and Russia.
- Different screw-based lamp growth rate assumptions.
- A more detailed assessment of CFLi quality issues.
- Reporting on quantified sales projections of other regulatory compliant lamp options aside from CFLi.

The global lamp market and industry is clearly undergoing a major transition. Technologies that have endured for over one hundred years are making way for more efficient and advanced options while regulatory activity is becoming proactive in accelerating these changes. The lamp market has become truly international and decisions can no longer be made in one locale without influencing the market situation in the rest of the world. The transition to the higher efficiency market is at a sensitive stage and care is needed to ensure it progresses in an efficient and orderly manner. Consequently, the IEA believes it is important for national and regional policy developments to continue to be informed by the wider international situation and for internationally coordinated responses to be considered and applied when appropriate. Accordingly, the IEA intends to continue to provide support to the policy development process and to assist exchange of information among regulators, industry and other relevant stakeholders.

Afterword: Post-EU regulations analysis

The analysis presented above in the main body of this report was completed and circulated to IEA member governments in July 2008 ahead of the adoption of regulations in a number of IEA countries including Europe. Subsequent to the original unpublished version of this study the EU adopted Commission Regulation (EC) No 244/2009 of 18 March 2009 "Implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps", which establishes minimum permissible efficacy requirements for the sale of new household lamps as set out below. This section presents analysis of the projected impact of these regulations on CFLi demand in place of the TREN Option1 Fast and TREN Option 2 Slow scenarios presented above.

EU Lamp Efficacy Requirements

There are six stages defined as follows:
Stage 1: 1 September 2009
Stage 2: 1 September 2010
Stage 3: 1 September 2011
Stage 4: 1 September 2012
Stage 5: 1 September 2013
Stage 6: 1 September 2016

Incandescent lamps with S14, S15 or S19 caps shall be exempted from the efficacy requirements of Stages 1 to 4 as defined in Article 3 of this Regulation, but not from Stages 5 and 6. The maximum rated power (Pmax) for a given rated luminous flux (Φ) is provided in Table A1.

The exceptions to these requirements are listed in Table A2 and the correction factors applicable to the maximum rated power are in Table A3.

Table A1. Minimum requirements

Application date	Maximum rated power (Pmax) for a given rated luminous flux (Φ) (W)	
	Clear lamps	Non-clear lamps
Stages 1 to 5	$0.8 \times (0.88\sqrt{\Phi}+0.049\Phi)$	$0.24\sqrt{\Phi}+0.0103\Phi$
Stage 6	$0.6 \times (0.88\sqrt{\Phi}+0.049\Phi)$	$0.24\sqrt{\Phi}+0.0103\Phi$

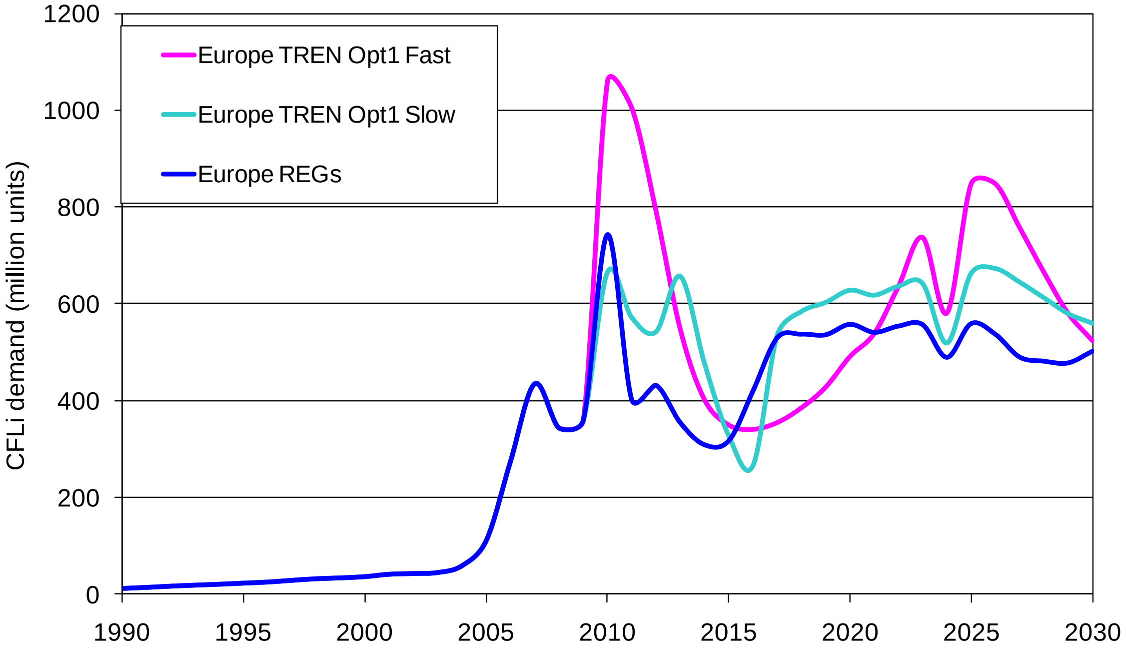
Table A2. Exceptions

Scope of the exception Maximum rated power (W)	Scope of the exception Maximum rated power (W)
Clear lamps 60 lm ≤ Φ ≤ 950 lm in Stage 1	$P_{max} = 1.1 * (0.88\sqrt{\Phi}+0.049\Phi)$
Clear lamps 60 lm ≤ Φ ≤ 725 lm in Stage 2	$P_{max} = 1.1 * (0.88\sqrt{\Phi}+0.049\Phi)$
Clear lamps 60 lm ≤ Φ ≤ 450 lm in Stage 3	$P_{max} = 1.1 * (0.88\sqrt{\Phi}+0.049\Phi)$
Clear lamps with G9 or R7s cap in Stage 6	$P_{max} = 0.8 * (0.88\sqrt{\Phi}+0.049\Phi)$

Table A3. Correction factors

Scope of the correction Maximum rated power (W)	Scope of the correction Maximum rated power (W)
Filament lamp requiring external power supply	Pmax/1.06
Discharge lamp with cap GX53	Pmax/0.75
Non-clear lamp with colour rendering index ≥ 90 and P ≤ 0.5 * (0.88√Φ+0.049Φ)	Pmax/0.85
Discharge lamp with colour rendering index ≥ 90 and Tc ≥ 5 000 K	Pmax/0.76
Non-clear lamp with second envelope and P ≤ 0.5 * (0.88√Φ+0.049Φ)	Pmax/0.95
LED lamp requiring external power supply	Pmax/1.1

Figure A.1. Projected CFLi sales in the EU in response to the adopted regulations plus showing the Option 1 Fast and Option 1 Slow phase-out regulatory options considered earlier



Source: IEA estimated.

Effectively these regulations prohibit the sale of traditional incandescent lamps (GLS) within the EU in stages from September 2009 to September 2012. For frosted lamps they only permit EU energy label class A lamps or better to be sold from September 2009 but for clear lamps the requirements are phased in such that all clear GLS are precluded from sale by September 2012 and that from September 2016 all clear lamps of whatever type and cap (base) have to be label class C or better. With such a complex array of requirements it is difficult to be sure what technologies will be demanded by end users because screw-based halogen lamps remain a competitor to CFLi throughout, although from 2016 only the more efficient and relatively expensive types are eligible.

The projected demand for CFLi under the adopted EU phase-out scenario is shown in Figure A.1. Also shown are the two aggressive phase-out scenarios considered in the rest of the report. Interestingly, while the projected total demand for CFLi is slightly less than for the TREN Option 1 Slow scenario the ramp up in demand is faster in 2010, although not as rapid nor does it reach such a high peak as for the TREN Option 1 Fast scenario.

The implication of this analysis is that the actual EU regulations are likely to influence global CFLi demand in a manner that is similar to the examples studied with the TREN Option 1 Slow scenarios rather than the Option 1 Fast scenarios. This implies that the demand profiles seen in Figures 6.1, 6.3 and 6.5 are closer to the likely global demand for CFLi (depending on the policy options adopted by China) than are those seen in Figures 6.2, 6.4 and 6.6.

The overall conclusions of the study addressed in Section 7 therefore remain valid.

References

Asawutmangkul, A. (2008) “Current situation of CFLs in Thailand”. Presented at *Phasing in Quality: Establishing a Quality Identification System for CFLs in Asia*, Asian Development Bank, Manila, Philippines.

Beletich, S. (2008). Personal communication.

Gonzalez, R. (2008). “The replacement of incandescent bulbs: The Cuban experience”. Presented at *Phase-out 2008*, Shanghai, May 12-16.

Hohn,. F. (2008). “Replacement Technologies to Incandescent lamps”. Presented at *Phase-out 2008*, Shanghai, May 12-16.

Huliganga, R.(2008). “Phase-Out Of Inefficient Lamps-Philippines”. Presented at *Phase-out 2008*, Shanghai, May 12-16.

IEA (2006) *Light’s Labour’s Lost: Polices for Energy Efficient Lighting*, IEA/OECD, Paris.

Kemco (2008). *Korea’s Energy Standards and Labeling: Market Transformation*, Korea Energy Management Corporation and the Ministry of Commerce, Industry and Energy.

OSI (2007). *OSRAM SYLVANIA Summary of the Energy Independence and Security Act of 2007, January 4, 2008*, OSRAM SYLVANIA.

Slade, M. (2008). “The Phase-out of Inefficient Lighting in East Asia”. Presented at *Phase-out 2008*, Shanghai, May 12-16.

Sun,. Y. (2008). “Replacement of Incandescent Lamps to CFLi in Japan”. Presented at *Phase-out 2008*, Shanghai, May 12-16.

USEPA (2007). “Confidence in Quality: Harmonization of CFLs to Help Asia Address Climate Change”, USAID in Asia, ECO-Asia Clean Development and Climate Change Program.

Waide, P. and B. Buchner (2008). “Utility energy efficiency schemes: savings obligations and trading” *Energy Efficiency* (forthcoming special edition on Tradable White Certificate Schemes) Springer.

Yan, E. (2008). “Replacement Technologies-CFLs”. Presented at *Phase-out 2008*, Shanghai, May 12-16.

Glossary and acronyms

Term	Description
Bayonet base lamp	Lamp with a bayonet fitting on its base.
CFLi	Compact Fluorescent Lamp with integrated ballast.
CFLn	Compact fluorescent lamp with a separate ballast – a modular design with the advantage that the ballast need not be replaced each time the lamp fails.
Capsule lamp	Variety of halogen lamp where the incandescing light source is enclosed in a small capsule that is either double ended or single ended (meaning it has electricity supply connections at one or two ends depending on the type).
CRI	Color Rendering Index
CCT	Color Correlated Temperature
Dichroic	Lamp (invariably halogen) using a multifaceted "dichroic" reflector.
Directional light source	Light source (lamp) whose light output is directed within a limited arc as opposed to an omni-directional light source. Examples include PAR, HL-R and GLS-R lamps.
ELV	Extra Low Voltage – typically refers to 12V DC halogen lamps operated with a transformer.
HL	Halogen lamp.
HL-R	Halogen reflector lamp.
GEF	Global Environmental Facility.
GLS	General Service Lamp (a conventional "A shape" incandescent lamp).
GLS-R	General Service Reflector Lamp (a conventional "A shape" incandescent lamp with a reflector to give more directional light output).
IEA	International Energy Agency
Incandescent lamp	Lamp that emits light through the process of incandescence.
IRC	Infra-red coating. The efficiency of halogen and other incandescing lamps is raised by applying an infra-red blocking coating on the inside of the lamp casing which reflects heat back onto the lamp filament and raises the operating temperature.
LED	Light Emitting Diode.
LV	Low Voltage.
LPW	Efficacy (Lumens Per Watt).
MEPS	Minimum Energy Performance Standard.
MV	Mains Voltage.
Omni-directional light source	Light source (lamp) whose light output is distributed in all directions such as conventional GLS and CFL.
PAR lamp	Parabolic Aluminised Reflector lamp – a type of incandescent reflector lamp that may or may not use a halogen filler gas.
Screw-base lamp	Screw-in lamp designed to fit into a standard Edison socket, although in this paper the term is also used generically to refer to all lamps using the most prevalent local fixture (*i.e.*, it also encompasses bayonet ended lamps in locals where bayonet lamps predominate).
SSL	Solid State Lighting.
Xenon Halogen	Halogen lamp using xenon gas in the bulb.

International Energy Agency

9 rue de la Fédération
75739 Paris Cedex 15

www.iea.org