Environment Bureau
The Government of the Hong Kong Special Administrative Region

Efficiency
EMSD

Final Report
For
Comprehensive Study on International Practice on Phasing Out Energy Inefficient Incandescent Lamps

Prepared by

Hong Kong Productivity Council
香港生產力促進局

November 2009

Executive Summary

1. As part of the Government's ongoing efforts to promote efficient use and conservation of energy, the Government would like to keep track of the recent worldwide development on phasing out of inefficient incandescent lamps and switching to more energy efficient ones so as to reduce carbon emissions. The Government commissioned Hong Kong Productivity Council (HKPC) to carry out comprehensive fact-finding study to benchmark the overseas practices and the various options adopted in phasing out of energy inefficient incandescent lamps as well as the practices and approaches in the phasing out schemes of these overseas countries; and the availability of viable and efficient alternatives for different categories of incandescent lamps. This report details the findings of the study and provides an overview of the different phasing out schemes developed by various countries. It should be noted that as the phasing out schemes of overseas countries are still evolving, this report provides a snap-shot of the information available at the time the report is prepared.

2. Incandescent lamps are commonly classified in accordance with their functional and technological characteristics. The functional classification for incandescent lamps is based on whether the lumen output is non-directional or directional. They are commonly named as non-reflector type lamps (or called non-directional lamps) and reflector type lamps (or called directional lamps). On the other hand, the technical classification is based on the in-fill gas types of the incandescent lamps and operating voltage of the lamps. Therefore under technical classification, lamps are commonly classified as (i) general lighting service (GLS) lamps, (ii) other tungsten filament lamps (such as candle-shaped, fancy round and decorative lamps, etc.) and (iii) main voltage and extra low voltage (ELV) halogen lamps. Countries such as USA, Canada and 27 EU member countries have generally put reflector lamps and non-reflector lamps into separate categories when setting the minimum energy performance standard (MEPS) for the incandescent lamps. However, Australia classified incandescent lamps differently using the technical classification approach for setting MEPS for its phasing out scheme. Thus, there is no unified classification approach in setting MEPS internationally and this sometimes makes it difficult to compare practices among different countries. For the purpose of this study, this report adopts the classification as listed in Table 1 such that incandescent lamps are classified into non-reflector and reflector lamps first, followed by technology classification into (i) GLS (note that there is no GLS for reflector lamps), (ii) other tungsten filament, (iii) main voltage halogen, and (iv) ELV halogen.

3. In view of the low energy efficiency characteristic of incandescent lamps which are still commonly used worldwide, different countries start to formulate their roadmaps to phase out these lamps. Many countries including 27 EU member countries, USA, Canada, Australia, Korea, Philippines, are imposing regulatory requirements to restrict sales and importation of energy inefficient incandescent lamps. In 2009 there will be several phasing out schemes to be tabled for approval / implemented in these countries. It should be noted that the phasing out schemes in these countries are usually extended over several years in order to allow the market adjusting to the change and allow efficient alternatives being available in the market. For instance, countries like EU member countries and Australia have adopted phasing out schemes from 2009 to 2012, while other countries will commence their schemes in 2012.

4. However, not all countries adopt mandatory phasing out schemes although it is a worldwide trend to switch to more energy efficiency lamps to replace the inefficient ones. For instance, countries like Japan, Thailand and UK have adopted voluntary programme instead. Other countries like China and Singapore are yet to review their situations before formulating roadmaps ahead.

5. One interesting observation worth mentioning is New Zealand as it declared in February 2009 that there is no plan to introduce regulatory requirements through MEPS in phasing out incandescent lamps. The original MEPS of New Zealand benchmarks closely with Australia's standard and was intended to be effective in middle of 2009.

6. All these findings point to the fact that the issue of phasing out incandescent lamps are not straight forward and needs very detailed consideration of local situations and overseas countries' schemes could not be simply replicated in other countries.

Survey on Phasing Out Schemes of Energy Inefficient Incandescent Lamps by Different Countries

7. Paragraphs 8 to 11 summarize briefly the phasing out schemes of some overseas countries as at September 2009.

8. The European Union has passed the legislative directive to phase out non-reflector (or called non-directional) type incandescent lamp with effective date of September 2009. The technical document for the phasing out scheme "Phasing Out Incandescent Bulbs" had been proposed by the EU on 8 December 2008. The report has acquired supports of the European Parliament and all 27 member states in turning it into laws in these member states. The EU has started to phase out GLS lamps starting from September 2009. In the mean time, the performance standard for compact fluorescent lamps (CFLs) is also being drafted to impose performance requirements on CFLs so as to avoid poor quality CFL lamps being sold to the customer to replace phased out incandescent lamps.

9. USA and Canada have adopted MEPS for the phasing out of non-reflector GLS lamps and other tungsten filament reflector lamps, but would still allow those higher efficiency halogen lamps to be continuously sold in the countries. USA sets the time frame from 2012 to 2014 for compliance with the MEPS, whereas Canada's compliance timeframe is set at 2012. In parallel, these two countries have also set regulatory requirements for compact fluorescent lamps (CFLs) after the implementation of MEPS for incandescent lamps.

10. Australia has been very active in the promotion of energy efficient appliance and she is also one of the pioneer countries in the setting of MEPS for the phasing out of inefficient incandescent lamps. The phasing out scheme covers almost all types of lamps including reflector and non-reflector, GLS, other tungsten filament, main and ELV halogen lamps. The scheme has been implemented with the first phase restriction on the importation of GLS lamps which is effective from February, 2009. The scheme intends to phase out the inefficient lamps and only allow those higher efficiency ones to be continuously sold and imported between 2009 to 2012.

11. In Asia, Korea and Philippines have also taken steps to implement restriction on the sale and importation of GLS lamps and halogen lamps. Korea has imposed the MEPS requirement on GLS lamps which has been effective since January 2009, and the target energy performance standard (TEPS) to align with other countries in 2012. Philippines has put forward a MEPS standard for the GLS lamp, tungsten filament lamp and tungsten for domestic and general lighting use in 2008. The act for "Incandescent Light Bulb Ban Act of 2008" has been pending for the approval of the senate committee. The act is planned to be effective on 1 January 2011.

12. Generally speaking, the commonly adopted approach for the phasing out of incandescent lamps in overseas countries is to enforce legislative requirements on the MEPS for incandescent lamps. Such approach is adopted by Australia, USA, Canada, EU, Korea and Philippines. Table 1 shows the types of incandescent lamps being covered in the MEPS schemes as adopted in these countries.

Table 1 – Lamp Types Included in MEPS Schemes of Different Countries

Country	Non-Reflector Lamps				Reflector Lamps	
	GLS	Other Tungsten Filament	Mains Voltage Halogen	ELV Halogen	All Tungsten Filament	Halogen (Mains and ELV)
EU 27 Countries	✓	✓	✓	✓	x	x
USA / Canada	✓	✓	✓	x	✓	x
Australia	✓	✓	✓	✓	✓	✓
The Philippines	✓	✓	✓	x	x	x
Korea	✓	x	x	x	x	x

13. On the other hands, some countries/territories adopted voluntary programs instead such as giving of incentive to encourage customers to buy and replace GLS lamps and non-reflector tungsten filament lamps with compatible CFL as adopted in Thailand, making agreements with retailers and manufacturers in switching the supply to CFLs in the market as adopted in Japan and the United Kingdom, etc.. All these voluntary programmes will also bring immediate benefits to the countries in lowering the penetration rate of inefficient incandescent lamps and reduce energy consumption.

14. United Kingdom (UK) has adopted the voluntary approach in making agreement with retails and manufacturers for ceasing the sale and supply of GLS lamps in the country. The initiative to phase out the basic general lighting service (GLS) light bulbs which comes from a joint and voluntary initiative between the UK lighting industry, retailers and the Government. The programme has been effective since January 2008 and gained commitment and support from the retailers and manufacturers with the joint coordination between the Lighting Association, retailers, manufacturers and the Energy Saving Trust. The voluntary programme will be gradually phase out by the newly launched EU directive on the phasing out of energy inefficient lamps in Europe starting from September 2009.

15. The main purpose of phasing out incandescent lamps in these countries is to improve the overall energy utilization efficiency for lighting and to promote CFLs and other alternatives to replace incandescent lamps. To avoid replacement of incandescent lamps

with CFLs of poor quality in the market, most of these countries also have regulatory requirements developed or being developed for CFLs.

Availability of Viable and Efficient Alternatives to Replace Incandescent Lamp

16. The study also includes a survey on the availability of viable and efficient alternatives to replace energy inefficient incandescent lamps. In assessing viable technology options of replacement, five criteria namely (1). efficacy, (2). lumen maintenance/depreciation, (3). start-up or re-strike time, (4).lighting control system, (5). light quality (lamp burn outs/lifetime and color rendering) of the replacement technologies were evaluated. Four technologies were identified as viable to replace incandescent lamps, namely CFLs, Metal Halide Lamps, Advanced Halogen Replacement Lamps (AHLs) (e.g. Halogen Infrared Reflecting Lamps, HIRs), and Light Effect Diodes/White Light Effect Diodes (LEDs/WLEDs). However, each of these viable technologies may have its own limitations rendering direct replacement of incandescent lamps sometimes not practicable or immediately feasible.

17. It was evaluated that apart from AHLs, many of the viable incandescent lamp replacement technologies are unable to fully meet all the criteria as mentioned above. Well developed CFLs come into various types and shapes which make them easier for users to match more applications but CFLs still cannot satisfy requirements for some decorative lighting usage. Metal Halide Lamps and LEDs have certain limitations such as narrow product range, not readily available in the retail level, and quality problem etc. Finally, although AHLs seem to meet all viability criteria, there are only very few manufacturers producing AHLs at retail level.

18. The four identified viable technologies are subject to further analysis to evaluate whether they are readily available for replacement of incandescent lamps. Six criteria were employed for such purpose including average lamp life, color rendering, color temperature, lamp base, luminous efficacy and wattage range. The evaluation revealed that

    a) For GLS, other tungsten filament non-reflector lamps and mains voltage halogen non-reflector lamps, there are available replacement technologies including CFL, AHLs, and LEDs (for low wattage application), as listed in Table 2.
    b) However for mains voltage and ELV reflector lamps, because of the special requirements of the lamps in specific applications, e.g. central beam luminous intensity, beam angle etc, there is no available replacement technologies on the market that can directly retrofit these lamps with similar or better lighting performance.
    c) For ELV halogen non-reflector lamp, due to the fact that the available replacement technology (i.e. AHLs) is limited, this replacement technology is not available at retail level.

19. The technologies available for replacement of incandescent lamps while recognizing certain limitations are as listed in Table 2.

Table 2: Available technologies listed against different types of incandescent lamps.

Type of Incandescent Lamp	Wattage Range (W)	Available Replacement Technology	Limitation
GLS	Up to 100W	1. CFL 2. LED 3. AHL	1. LED is available for replacing low wattage incandescent lamps only 2. Lower CRI of LED may not match requirement for specific applications 3. Size and shape of LED may not suit all application requirements 4. Higher lamp cost
	100W to 200W	1. CFL	1. Size and shape of CFL may not suit all application requirements (e.g. stage lighting fixtures) 2. Higher lamp cost
Other Tungsten Filament Lamps	All wattage	1. CFL 2. AHL	1. Lower CRI of CFL may not match requirement for specific applications 2. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely available in the retail market 3. Higher lamp cost
Mains Voltage Halogen Non-reflector Lamps	Up to 150W	1. CFL 2. AHL	1. Size and shape of CFL may not suit all application requirements (e.g. decorative lighting fixtures) 2. Lower CRI of CFL may not match requirement for specific applications 3. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely available in the retail market 4. Higher lamp cost
	200W to 500W	1. AHL	1. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely available in the retail market 2. Higher lamp cost
Mains Voltage Halogen Reflector Lamps	All wattage	No available replacement	1. Light beam characteristics such as center beam intensity and beam angle are not fully complied.
ELV Halogen Non-reflector Lamps	All wattage	1. AHL	1. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely available in the retail market 2. Higher lamp cost
ELV Halogen Reflector Lamps	All wattage	No available replacement	1. Light beam characteristics such as center beam intensity and beam angle are not fully complied.

Remarks

20. The study has reviewed the phasing out schemes of some overseas countries and studied the technical information and viable replacement options of the incandescent lamps. It should be noted while some countries like USA, Canada and EU countries have phasing out schemes in place, such schemes are usually extended over several years in order to allow the market to adjust to the change. For other countries like Japan, Thailand and UK, they have adopted voluntary programme instead. Still other countries like China and Singapore are yet to review their situations before formulating roadmaps ahead.

21. Such findings point to the fact that the issue of phasing out incandescent lamps are not straight forward and needs very detailed consideration of local situations and overseas countries' schemes could not be simply replicated in other countries.

22. Benchmarking against the experience of these countries, if the Government is considering any scheme to phase out incandescent lamps, it is recommended that

    (i) the scope should be limited to mains voltage non-reflector lamps with available replacement options, such as GLS lamps, other tungsten filament lamps, etc.

    (ii) there should be phased implementation of the phasing out schemes, allowing time to fine-tune the scheme after implementation of initial phases, and when considering which type of lamps is to be phased out first, due regards must be given to

    (a) potential energy saving
    (b) availability of replacement option in the market
    (c) stakeholder's views
    (d) price and quality of the replacement lamps

    It is also in line with the international practice.

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1. Introduction

In view of the low energy efficiency of incandescent light bulbs which are still commonly used by consumers in many countries / territories, international efforts are being collaborated to tackle climate change by reducing the greenhouse gas emissions through formulating roadmaps to phase out the inefficient incandescent lamps. Many countries including Australia, 27 EU member countries, United States, Canada, Korea, Philippines, have respectively taken steps to phase out the sale and importation of energy inefficient incandescent light bulbs recently. It is a worldwide trend to switch to more energy efficient lamps and obsolete the inefficient ones.

As part of the Government's ongoing efforts to promote efficient use and conservation of energy, the Government would like to keep track of the recent worldwide development of phasing out of inefficient incandescent lamps and switching to more energy efficient ones so as to reduce carbon emissions. The Government had commissioned Hong Kong Productivity Council to carry out a comprehensive study to benchmark the overseas practices on phasing out of energy inefficient incandescent light bulbs as well as the nation's practices and approaches in the exercise, and the availability of viable and efficient alternatives for different categories of lighting etc.

This comprehensive study aims to provide information about international practices and approaches on the phasing out programmes which are current in place or being developed in other countries; viable lamp technologies for replacing inefficient incandescent lamps and potential replacement options with acceptable output quality.

As the phasing out programmes are evolving, this report provides a snap-shot of the information available as at September 2009. This report consists of findings on international practices and programmes, viable lamp technology and potential replacement options as for the concerns of phasing out incandescent lamps worldwide.

1.1 - Overview of International Practices on Phasing Out Programmes for Inefficient Incandescent Lamps

A list of overseas countries that are implementing different schemes and programmes on limiting the sale and importation of incandescent lamps are identified in the study. The results are presented in table format, with information on type of scheme (voluntary or mandatory) implemented or planning to be implemented in the near future.

Among these countries, the details of ten major countries are summarized including Australia, New Zealand, 27 member countries / territories of European Union, United Kingdom, US, Canada, China, Japan and South Korea and Singapore.

Information for scope of lamps included in various phasing out program and their regulatory regimes is presented in this report.

1.2 Study on Viable Technology and Potential Replacement Options

In this section we will study the viable lamp technologies and potential replacement options for replacing different type of incandescent lamps. Replacement options with output quality comparable to that of incandescent lamps, application concerns and availability are discussed.

2 Overview of International Practices on Phasing Out Programmes for Inefficient Incandescent Lamps

In this section we will take a glance on the recent developments of oversea countries / territories for the phasing out programmes of inefficient incandescent lamps and other policy schemes for the promotion of energy efficient lamps as at September 2009.

2.1 Recent International Development in the Phasing Out of Inefficient Incandescent Lamp

Incandescent light bulbs are inefficient as compared with other energy efficient alternatives, like compact fluorescent lamps and LED lamps etc. In order to phase out energy inefficient lamps in the market and to promote the use of more energy efficient lamps, there are different types of mandatory and voluntary schemes developed in different countries. Some countries have started reviewing their needs to establish laws and regulations in accelerating the phasing out exercise so as to avoid importing inefficient lamps. For example, Australia has implemented import restriction since February 2009 whereas USA and Canada will put their programmes effective in 2012. Most of these law and regulation are established through setting up of minimum energy performance standards for lamps so as not to ban the lamp type and technology in the market. In the following section, the recent development of the phasing out programmes as adopted in different nations is provided.

2.1.1 Americas

Some of the America countries have already taken steps to restrict the sale, manufacture and importation of inefficient incandescent lamp. USA and Canada adopts minimum energy performance standards in phasing out the inefficient incandescent lamps, but would still allow those higher efficiency one such as halogen lamps to be used in the country.

a) In **United States** on December 19, 2007, the Energy Independence and Security Act of 2007 was signed by President George W. Bush into law (become Public Law 110-140). The new law stipulates the minimum energy efficiency standard for implementing energy efficiency requirement on non-reflector type general service lamps (GLS)[1] and modified spectrum[2] incandescent bulbs that produce 310 - 2600 lumens of light (by January 2014). Bulbs outside this range (roughly, light bulbs currently less than 40 Watts or more than 150 Watts) are exempt from the ban. Also exempted are several classes of specialty lights, including appliance lamps, "rough service" bulbs, 3-way, colored lamps, and plant lights. The Act also includes coverage

[1] Disregarding the different nomenclatures being used in different countries, incandescent lamps for general service use is given an abbreviation of GLS throughout this report.

[2] Modified spectrum lamp that has Glass globes contain neodymium or are coated with neodymium glass frit to filter out yellow and are sold for health reasons

of Bulged Reflector (BR), Elliptical Reflector (ER), and Blown Parabolic Aluminized Reflector (BPAR) type incandescent reflector lamps, in addition to the Standard Reflector (R) and Parabolic Aluminized Reflector (PAR) lamps as set out in the 1992 legislation.

The scheme will be implemented in two phases. The first phase will be effective in January 2012 for light bulb ranging from 310 lumens to 2600 lumens which requires 25%-30% power savings from today's incandescent. Phase two will require all reflector type incandescent lamps to meet the efficacy with at least 45 lumens/watt and will be effective on January 2020. The final phase will be further determined by Department of Energy (DOE), rulemaking to be completed by 1 January 2017.

Major initiatives or programmes on phasing out inefficient incandescent lamps are being implemented or formulated in different states of USA. For example in California, the Energy Commission adopted the first MEPS for GLS lamps (proposed by PG&E) in 2004 and legislative proposal to phase out incandescent bulb sales by 2012 is being discussed.

b) In **Canada,** the Ontario's Minister of Energy Dwight Duncan announced in April 2007 that the provincial government intended to phase out the inefficient incandescent light bulbs by 2012. Subsequently the Federal Environment Minister John Baird announced a plan to phase-out inefficient light bulbs in Canada by 2012, but not the banning of the incandescent light bulb technology as a whole. The proposed standard has passed the pre-publication (75 days) in the Canada Gazette Part I in October 2008 and the new amendments obtained the final approval and were publicly announced in the Canada Gazette Part II in January 2009. The regulation for the MEPS Standard covers Non-reflector type GLS incandescent lamps and modified spectrum incandescent lamps with lumen ranging from 250 lumens to 2600 lumens with effective on 1/1/2012 for 1050-2600 lumens (75W to 100W) and 31/12/2012 for 250-1040 lumens (40W to 60W) respectively. The regulation sets the phasing out schedule for inefficient General Service Incandescent Lamps (GLS) and modified spectrum incandescent lamps.

The MEPS standard for incandescent reflector lamps has been firstly implemented in 1995 which covered R, PAR and lamps with similar bulb shapes. The standard was amended to cover ER and BR lamps in 2003. Latest news indicated that the Canada Government will impose further stringent requirement on the energy efficiency requirement for the reflector lamps in 2009. The newly amended MEPS standard will cover Bulged Reflectors (BR), Elliptical Reflectors (ER), Reflectors (R), Parabolic Reflectors (PAR), Blown Parabolic Reflectors (BPAR) and lamps of similar shapes. The approval is subject to the publication of the new regulation for the MEPS standard for incandescent reflector lamps at *Canada Gazette*, Part II is expected to be in 2009.

c) **Argentina's** President Cristina Kirchner has sent a bill to Congress in March of this year calling for the end of incandescent lamps for residential use in Argentina by 2010. Citing energy conservation and global warming concerns, the brief bill has received the approval of groups as disparate as Greenpeace and the Chamber of Electronic, Electromechanical and Lighting Industries (CADIEEL). With the support of CADDIEEL for the bill, the bill was passed by the Senate of the country at the end of

2008. Under the requirements of the bill, the importing and commercialization of non-reflector GLS incandescent light bulbs for residential use will be forbidden in the country starting from 31 December, 2010. The bill empowers the Government to establish exceptions to the rule for, "technical, functional and operative reasons." It is still unclear about whether the Argentina Government will set the MEPS for this purpose. The bill will become law and be enforced when it is published at the governmental Official Bulletin.

2.1.2 Asia

a) **China** does not have any legislative plans in phasing out incandescent lamp at the current moment. As expressed by Mr. Pengcheng Li of China National Institute of Standardization (CNIS) (Sub-Institute of Resource & Environment Standardization) in September 2008, it was learnt that China is currently studying the feasibility of phasing out inefficient incandescent lamp in China. Inevitably China will consider the timetable and complementary measures for phasing out incandescent although there are no official policies/regulations/plans to phase out in national or municipal level. Therefore the detailed practice or approach is still in the absence.

However, the China Government has initiated some of the promotional programmes and setting goals in different aspect so as to achieve further energy saving by using more energy saving lamps. In April 2008, National Development and Reform Commission (NDRC) and Ministry of Finance (MOF) announced a major programme to promote efficient lighting products nationwide. The Chinese government will subsidize 50 million high efficient fluorescent lamps (focuses on CFL, T5 and T8) for three years (a total promotion of 150 million lamps). Financial subsidies will be 50% for family users and 30% for bulk users. During the "nationwide promotion of high efficient lighting products" meeting in April 2008, Mr. Xie Zhenhua, the deputy director of NDRC pointed out that the China government will cooperate with GEF and UNDP on the project of "Phasing Out Incandescent Lamps, Speeding Up the Promotion of Energy-saving Lamps", and support China's incandescent lamps production manufacturers to switch to CFL production.

b) Although **Japan** Government does not have a legislative plan to phase out the incandescent lamps, they have actively sought the cooperation with stakeholders in the lamp industry in the promotion of energy efficient lamps in the country. In December 2006, Japan Electric Lamp Manufacturers Association (JELMA) has already announced 4 proposals of energy saving by lamp replacements to be followed by the manufacturers: GLS incandescent lamps to compact fluorescent lamp with integral ballast (CFLi); tungsten halogen to compact fluorescent lamps and ceramic metal halide lamps; fluorescent lamps to HF-type lamps (High Frequency Operating type); and high pressure mercury lamps to metal halide and high pressure sodium lamps. In April 2008, Mr. Amari, minister of METI, announced the replacement policy for GLS incandescent to CFLi by 2012.

Since then, some of lamp manufacturers announced their target time of their full replacement from GLS incandescent to CFLi by 2010. Under the policy, incandescent lamps are divided into two groups: Group A – E26 base lamps for general lighting (with a target that 70% of Group A will be replaced to CFLi), remained used for dimming, spot lighting and decoration. Group B – Lamps for special lighting uses (remained for use in the market)

c) In **Korea**, target energy performance standards (TEPS) and minimum energy performance standards (MEPS) are currently applied to non-reflector GLS incandescent lamps. MEPS aims to expel inefficient designs from the market, while TEPS are designed to encourage manufacturers to produce more energy-efficient goods.

Under the program, manufacturers (importers) are mandated to produce and sell GLS incandescent lamps that meet the required MEPS. At the same time, they are also required to comply with the mandatory Energy Efficiency Label and Standard Program for GLS incandescent lamps. This program is Korea's core energy efficiency management scheme. The Energy Efficiency Label and Standard Program enables consumers to identify high efficiency energy efficiency products easily by (1) mandatory indication of energy efficiency grade from 1st to 5th grade; (2) mandatory reporting of energy efficiency grade by manufacturers; and (3) applying minimum energy performance standard – MEPS. Production and sales of products that fall below the 5th grade is prohibited (Applying MEPS). In case of violation, a fine up to 20 thousand Korea dollars (WON) will be charged. New MEPS for Incandescent Lamps has been put effective on 1 January 2009 and required to accomplish Targeted Energy Performance Standard set forth before 31 December 2012.

d) **Philippines's** President Gloria Macapagal Arroyo called for a phasing out of incandescent light bulbs by 2011 in favor of more energy-efficient fluorescent globes to help cut greenhouse gas emissions and household costs during her closing remarks at the Philippine Energy Summit in 2008. Once put in effect, the country will be the first in Asia to phase out incandescent bulbs. As expressed by Ms. Raquel S. Huliganga, Director of Energy Research and Testing Laboratory Services in September 2008, Department of Energy, Philippines is moving towards to phase-out non-reflector lamps including GLS lamps, other tungsten filament lamps and halogen lamps. Special application incandescent bulbs will not be included (i.e. refrigerator bulbs, efficient halogen lamps, etc). Philippines has put forward a MEPS standard for the GLS lamp, tungsten filament lamp and tungsten for domestic and general lighting use in 2008. The act for "Incandescent Light Bulb Ban Act of 2008" has been pending for the approval of the senate committee. The act is planned to be effective on 1 January 2011.

e) **Singapore** currently does not have any existing policies or regulations to ban or phase out incandescent lamps, as expressed by Zulkarnain B H Umar, the Senior Engineer of Regulation Division of Energy Market Authority of Singapore. Singapore only has the Mandatory Energy Labelling Scheme (MELS) for household air-conditioners, refrigerators and cloth dryers in 2009.

f) **Thailand** currently has policy for voluntary phasing out incandescent lamps initiated by the Demand Side Management Office of the Electricity Generating Authority of Thailand (EGAT), which is responsible for the improvement of energy efficiency of household appliances, as expressed by Gunn Saengruang, EGAT of Thailand Government. Up till now, they are all voluntary programmes and no National policy has been formulated for the purpose of phasing out the incandescent lamp. Thailand Government is focusing on the demand side rather than banning the further production of incandescent lamps on the supply side by campaigning the greater use of efficient CFLs through labeling scheme and price incentive.

In 2007, Thai Minister of Energy (Dr. Piyasvasti Amranand) announced on 21 March plans for a national campaign to subsidize the sale of energy-saving compact fluorescent lamps (CFLs) and work with Thai suppliers to phase out the sale of incandescent lamps. As a result, Thai government through Energy Conservation Fund provided a THB 80 million (US$ 2.3 million) fund for EGAT to implement the program to reduce the cost of CFLs, and that this would help to voluntarily phase out the sale of incandescent lamps within three years. Under this project, 2 major activities have been practiced – (1) giving away at CFL's and half market price CFLs selling. 800,000 CFLs were to be given away to the end-user (one CFL for one household). And, (2) for half-price CFL plan, EGAT would buy a large number of CFLs to get lower than market unit price CFL. The CFLs are then resold to market at the price purchased by EGAT under EGAT's particularly designed packaging to ensure the creditability of the CFLs by using EGAT brand.

The amount of 4.2, 10 and 15 million lamps would be purchased and resold in 2008, 2009 and 2010 accordingly. Parallelly, there are policies and efforts to revolve CFLs voluntary labeling to the enforced labeling, to ensure that all customers would be informed the efficiency of CFLs. Likewise, it is estimated that the minimum energy performance standard (MEPS) for CFLs would come into action within 2010, the year that Thailand plan to reach its goal of phasing out the incandescent lamps usage throughout the country.

2.1.3 Europe

The European Union has passed the new directive on the phasing out of inefficient non-reflector (or called non-directional) type incandescent lamps by year 2012 with effective date in September 2009. The technical document for the "Phasing Out Incandescent Bulbs" in the EU had been proposed by the EU on 8 December 2008. The report has received supports of the European parliament and all 27 member states and has become law since March 2009. The new directive requires the EU to phase out the conventional bulbs gradually starting from September 2009 till September 2012. The European Lamp Companies Federation (ELC), representing leading lamp manufacturers in Europe and CELMA, as well as luminaries and ballasts producers in Europe, has supported the EU decision aiming at restricting incandescent lamps in Europe by 2012 and low efficiency halogen lamps by 2016.

The phasing out of inefficient incandescent lamps and replacement by energy saving bulbs and energy efficient lamps will help the EU consume almost 75% less energy than the traditional kind of bulbs. The industry also expect that this initiative could reduce CO2 emissions by 60% (23 mega-tonnes a year) generated by domestic lighting and achieve a saving €7 billion, an annual 63,000 GWh of electricity. This initiative is part of the energy efficiency action plan, adopted by the Commission in November 2006, which aims to cut the EU's energy consumption by 20% by 2020.

As for other countries in the EU region, some of them have started to implement their own programmes to promote the use of energy efficient lamps.

UK has adopted the voluntary approach in making agreement with retails and manufacturers in stopping the sale and supply of GLS lamps in the country. The initiative to phase out the basic general lighting service (GLS) light bulbs which comes from a joint and voluntary initiative between the UK lighting industry, retailers and the Government. On 27 September 2007, the government in the United Kingdom announced plans to phase out the sale of incandescent light bulbs by 2011. Under the plan, retailers will voluntarily decline to stock 150-watt bulbs from January 2008, 100-watt bulbs from January 2009, 60-watt bulbs in 2010, and all remaining bulbs by 2011. The programme has been effective since the Jan 2008 and gained commitment and support from the retailers and manufacturers with the joint coordination between the Lighting Association, retailers, manufacturers and the Energy Saving Trust. The voluntary plan has gained wide support from retailers and consumers with schedule below.

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

In accordance with the newly passed EU directive on the phasing out of energy inefficient lamps in European Union, the UK voluntary programme will be gradually replaced by the mandatory programme.

Italy has planned to phase out the sale of incandescent light bulbs as of 2010 by setting of energy efficiency standard requirement.

Netherlands is moving ahead with plans to phase out incandescent light bulbs as well. The Dutch minister Environment Jacqueline Cramer wants a phase out of incandescent light bulbs within 4 years.

Ireland government has passed the legislative requirement on the minimum energy performance standard for GLS lamp and has been effective since January 2009. This makes it the first European nation to outlaw the old energy hogging bulbs. All ordinary old incandescent light bulbs are restricted for sale and importation in Irish market starting in January 2009. As incandescent bulbs break, Irish citizens will have to replace them with more energy efficient options such as (CFL) bulbs. The phasing out of the old style bulbs will be done in a four stage process up until 2012, beginning in March 2009. GLS lamps which have an electrical power consumption of 75 watts or higher will be removed from the shelves first, followed by various other types over the next three years.

2.1.4 Oceania

Australia has been very active in the promotion of energy efficient appliance and she is also one of the pioneer countries in setting of minimum energy efficiency standard for the phasing out of inefficient incandescent lamps.

a) In **Australia,** since the announcement for the phasing out of all types of incandescent lamps by the Australian Federal Government on February 20, 2007, the legislation on the Minimum Energy Performance Standards (MEPS) AS/NZS 4934.2-2008 for general purpose incandescent lamps (tungsten filament and tungsten halogen) has been passed and commenced on 30 November 2008. The required test procedures for incandescent lamps are set out in AS/NZS 4934.1-2008. Subsequent implementation timetable starting with the restriction on import for the GLS has commenced on February 2009. With reference to the Australian Customs Notice No. 2009/04 dated February 2009, the importation of General Lighting Service (GLS) Electric Filament Lamps are prohibited under the *Customs (Prohibited Imports) Regulations of Australia* from 1 February 2009. Person who wants to import the GLS lamps is required to obtain permission from the Minister for Environment, Heritage and the Arts prior to the importation. Permissions will only be granted in a limited number of circumstances. The maximum penalty for importing these goods without import approval is a fine not exceeding $110,000 or 5 times the value of the goods, whichever is the greater.

Other types of incandescent lamps will be gradually put under the requirement of the MEPS in a 4 years phase out period. From November 2009, the sale and retail of non-compliant GLS lamps in Australia will be restricted under the new requirement of MEPS. The proposal in 2008 has included the MEPS for extra low voltage converter for low voltage incandescent lamps as required in "Performance of electrical lighting equipment - Transformers and electronic step-down converters for ELV lamps - Part 2: Energy labelling and minimum energy performance standards requirements" which is to be required in the whole phasing out programme.

According to the requirement, all types of incandescent lamp that are sold in Australia will have to meet the new minimum energy performance standards. The new minimum standard efficiency level is set by a formula which have higher efficiency requirement for higher lumen output lamps (e.g. 15 lumens per watt (lm/w) for a 900 lumen lamp and 17 lumens per watt for a 1800 lumen lamp). This standard is expected to effectively prohibit the sale of most of the inefficient incandescent lamps available prior to that date. High efficiency halogen bulbs will still be available provided that they meet the new minimum energy performance standards. The application for the registration of incandescent lamp can be done on the Australia's Government web site.

It is estimated that greenhouse gas emissions will be cut by 800,000 tonnes (Australia's current emission total is 564.7 million tonnes), a saving of approximately 0.14% after the implementation of the whole phasing programme in Australia.

b) **New Zealand** is also setting similar phasing out measures for inefficient incandescent lamps as adopted in Australia but current news indicated that the plan is put on hold by the new Government. Initially the NZ Government intended to adopt the same minimum energy performance standards of Australia for lighting. The Efficient Lighting Strategy was launched in June 2008 with a target to reduce lighting energy consumption by 20% by 2015 by the Energy Efficiency and Conservation Authority of NZ Government. The standard's requirement, equivalent to the Australian's one as described in the "Greenlight Australia" was expected to be effective starting from October 2009. As the plan is now on hold, however, it is still unclear about when the phasing out scheme will be resumed for further planning.

2.1.5 Summary of International Development

The study has reviewed the phasing out schemes of incandescent lamps of some overseas countries. It should be noted while some countries like USA, Canada and EU countries have phasing out schemes in place, such schemes are usually extended over several years in order to allow the market to adjust to the change. The development of phasing out scheme in these countries adopt the MEPS approach for the phasing out of incandescent lamps including non-reflector type GLS lamps, tungsten filament and halogen lamp.

Some countries including Japan, UK and Thailand have adopted voluntary approach to encourage use of CFL lamps in the market. Most of these countries have accelerated the development and legislation process in the setting of phasing out programmes so as to meet the latest environmental requirement on reducing energy consumption and carbon emission due to the lighting use in the countries. It is worthwhile to note that almost all countries adopt a phased implementation of the phasing out exercise. Other countries like China and Singapore are yet to review their situations before formulating roadmaps ahead.

Such findings point to the fact that the issue of phasing out incandescent lamps are not straight forward and needs very detailed consideration of local situations and overseas countries' schemes could not be simply replicated in other countries.

Benchmarking against the experience of these countries, if the Government is considering any scheme to phase out incandescent lamps, it is recommended that

(i) the scope should be limited to mains voltage non-reflector lamps with available replacement options, such as GLS lamps, other tungsten filament lamps, etc.

(ii) there should be phased implementation of the phasing out schemes, allowing time to fine-tune the scheme after implementation of initial phases, and when considering which type of lamps is to be phased out first, due regards must be given to
(a) potential energy saving
(b) availability of replacement optical in the market
(c) stake holder's views

(d) price and quality of the replacement lamps
It is also in line with the international practice.

In the next section we will take a glance on the development scheme adopted in these countries that have adopted MEPS scheme, voluntary scheme with details.

2.2 Phasing Out Programmes in Major Countries

In this section, important mandatory phasing out schemes and voluntary programmes that have been developed or being developed in other countries are provided in the comparison tables 2.2(a) and 2.2(b) respectively.

Table 2.2(a) Comparison Table for MEPS Schemes

<table>
<tr><th>Country</th><th>Phasing Out</th><th>MEPS Scheme</th><th>Effective Date</th><th>Covered Lamp Types [1&2]</th><th>Excluded Lamp Types [1&2]</th><th>Remark</th></tr>
<tr><td rowspan="2">Australia</td><td>Incandescent lamps, for types mentioned in the table,</td><td>Minimum energy performance standards (MEPS) for inefficient incandescent light bulbs</td><td><table>
<tr><th>Lamp Types</th><th>for Import</th><th>for Sale</th></tr>
<tr><td>GLS</td><td>1 Feb 2009</td><td>Nov 2009</td></tr>
<tr><td>ELV halogen non-reflector</td><td>N/A</td><td>Nov 2009</td></tr>
<tr><td>>40W Candle, fancy round and decorative lamps, Mains voltage halogen non-reflector, ELV halogen reflector</td><td>Nov 2009*</td><td>Nov 2010</td></tr>
<tr><td>Mains voltage reflector lamps including halogen (PAR, ER, R, etc), >25W Candle fancy round and decorative lamps</td><td>Nov 2011*</td><td>Nov 2012</td></tr>
<tr><td>Pilot lamps 25W and below</td><td colspan="2">Subject to review</td></tr>
</table>* The feasibility of import restrictions is the subject of ongoing investigations</td><td>1. The proposed MEPS is based around a minimum efficacy level of 15 lumens/watt for an 900 lumen incandescent lamp
2. There is a sliding scale for other lamp sizes, with progressively lower MEPS for lamps providing less than 900 lumens and progressively higher MEPS for lamps providing more than 900 lumens. The requirements are defined by the following formula.
<u>Initial efficacy ≥ 2.8 * ln (initial lumens) – 4.0</u>
3. lifetime (≥ 2000 h)
4. lumen maintenance (80%, measured at 75% of rated life)
5. It is expected that this MEPS will affect the tungsten filament lamp, but may not affect the tungsten halogen lamp as there are product with efficiency higher than the requirement</td><td>Lamps that used in activities with intensive or special lighting requirements:
a. traffic management
b. operating theatres
c. stage productions
d. photography and movie-making
e. activities requiring enhanced spectrum lamps, such as specialty horticulture and aquaculture</td><td>It is also proposed that only lamps that significantly exceed the MEPS can be designated as ‘high efficiency’, possibly 75% more efficient. The current generation of tungsten halogen lamps would not qualify as high efficiency lamps.</td></tr>
<tr><td>Extra Low Voltage Converter</td><td>MEPS for ELVC is being drafted by the government</td><td>The MEPS apply to the sale of lamps and ELVCs. Implementation will commence in November 2009, with grace period to 2012</td><td><table>
<tr><th>Rated power level</th><th>MEPS (% eff at full load)</th></tr>
<tr><td>≤ 200 VA</td><td>≥ 86%</td></tr>
<tr><td>> 200 VA</td><td>≥ 91%</td></tr>
</table></td><td></td><td></td></tr>
</table>

Country	***Phasing Out***	***Control Scheme***	***Effective Date***	***Covered Lamp Types*** [1&2]	***Excluded Lamp Types*** [1&2]	***Remark***
Canada	GLS Incand-escent lamp	Mandatory MEPS for lamps imported or shipped inter-provincially for sale or lease in Canada	For GLS 1050 – 2600 lm, 1/1/2012 250 – 1049 lm, 31/12/2012 For Modified Spectrum 1050 – 2600 lm, 1/1/2012 250 – 1049 lm, 31/12/2012 The Proposed Regulation has been published and passed in Canada Gazette Part I and Part II in October 2008 and January 2009 respectively.	"General Service Lamp" includes *(a)* has a luminous flux of at least 250 lm but no greater than 2600 lm, *(b)* has a nominal voltage or voltage range that lies at least partially between 100 volts and 130 volts, and *(c)* is screw-based, *(d)* min. Life 1000 hrs *(e)* CRI>0.8 For GLS Efficiency Requirement - Efficacy Curve : >=4.0357 x ln(lumen output) – 7.1345 For Modified Spectrum Efficiency Requirement: 75% x Efficacy Requirement Value as specified in GLS Efficacy Curve (Modified spectrum has the glass globes contain neodymium or are coated with neodymium glass frit to filter out yellow)	Does not include a) an appliance lamp, b) an integrally ballasted CFL, c) coloured lamp, d) explosion resistant lamp, an infrared lamp, e) lamp that has a G-shape as defined in ANSI C78.20, with diameter of 13 cm or more, f) showcase lamp, T-shape as specified in ANSI C78.20 with max.40 W, length exceeds25 cm, g) solid state technology LEDs lamp h) left-hand thread lamp, i) plant lamp, j) incandescent reflector lamp with shape stated in NEMA C79.1, k) sign service lamp, (*p*) silver bowl lamp, , (*q*) traffic signal module, pedestrian module or a street light, (*r*) submersible lamp, (*s*) lamp that has a screw base size of E5, E10, E11, E12, E17, E26/50×39, E26/53×39, E29/28, E29/53×39, E39, E39d, EP39 or EX39 as stated in ANSI C81.61, (*t*) lamp type B, BA, CA, F, or M-14 shape or other similar shape, as specified in ANSI C78.20 and NEMA C79.1, and a max. of 40 W;	The scheme has been approved for publication on Gazette Part I and Part II in October 2008 and January 2009 respectively

Country	*Phasing Out*	*Control Scheme*	*Effective Date*	*Covered Lamp Types* [1&2]	*Excluded Lamp Types* [1&2]	*Remark*
Canada	Incand-escent Reflector lamp	Mandatory MEPS for lamps imported or shipped inter-provincially for sale or lease in Canada	The first Canadian Energy Efficiency Regulations effective on Apr 1996 included general service incandescent reflector lamps with minimum performance requirements consistent with the U.S. Energy Policy Act of 1992 and covered R, PAR and lamps with similar bulb shapes. The regulation has been amended in 2003 to cover the ER and BR lamps. The newly proposed standard for the reflector lamps is subject to final approval and publication at Canada Gazette Part II in 2009 as below. **RATED WATTAGE (W)** / **MINIMUM AVERAGE LAMP EFFICACY (lm/W) R,BR,ER and PAR Lamps** 40 – 50: 10.5 51– 59: 11.0 60 – 85: 12.5 86 – 115: 14.0 116 – 155: 14.5 156 – 205: 15.0	**General service incandescent reflector lamps** Include R bulb shape, PAR bulb shape, ER bulb shape, BR bulb shape or any bulb of similar shape with: a. a medium screw base, b. a nominal voltage between 100 volts and 130 volts, c. a nominal diameter greater than 57 mm (2.25 inches or 18/8 inches), and d. a nominal power of 40 W or greater. **BR lamps** – Incandescent reflector lamp as described in ANSI C79.1, but does not include BR30 (95 mm) and BR40 (127 mm) of 50 Watts or and BR30 and BR40 lamps of 65 Watts. **ER lamps** –the ER30 (95 mm) and ER40 (127 mm) of 50 Watts or less and the ER40 of 65 Watt would be exempt from the Regulations the Regulations would exempt R lamps with a diameter of smaller or equal to 63.5 mm (R 20) and a rated power ≤ 45 watts	Does not include the following GLS Reflector Lamp: 1. a coloured incandescent reflector lamp; or an incandescent reflector lamp that is of the rough or vibration service type with: i) a C-11 filament, as described in the IES Handbook, with five supports exclusive of lead wires; ii) a C-17 filament, as described in the IES Handbook, with eight supports exclusive of lead wires; or iii) a C-22 filament, as described in the IES Handbook, with 16 supports exclusive of lead wires; 2. is of the neodymium oxide type 3. has a coating or other containment system to retain glass fragments if the lamp is shattered and is specifically marked and marketed as an impact-resistant lamp; 4. is specifically marked and marketed for plant growth use and has a spectral power distribution that: i) is different from that of the lamps described in paragraphs (a) to (e) of covered lamp types; and ii) promotes the growth of plants; or iii) is specifically marked and marketed iv) as an infrared heat lamp; v) for heat-sensitive use vi) for mine use; or for aquarium, terrarium or vivarium use.	Subject to more stringent regulations for ER/BR lamps in 2009

<table>
<tr><th>Country</th><th>Phasing Out</th><th>Control Scheme</th><th>Effective Date</th><th>Covered Lamp Types</th><th>Excluded Lamp Types</th><th>Remark</th></tr>
<tr><td>Korea</td><td>GLS Incand-Scent lamps</td><td>MEPS and TEPS for GLS Incandescent Lamps</td><td>New MEPS for GLS Incandescent Lamps, effective 1/1/2009 and required to accomplish Targeted Energy Performance Standard set forth before 31/12/2012

Apply for both import and domestic goods, production and sell</td><td colspan="2">General Service Lamps GLS (known as White tungsten bulb in Korea) at 220V of rated power of 25~150W.

(unit : lm/W)
<table>
<tr><th rowspan="2">Rated Power (P)</th><th>TEPS</th><th>MEPS</th></tr>
<tr><th>To 31st of December, 2012</th><th>From 1st of January, 2009</th></tr>
<tr><td>25W≤P<40W</td><td>10.9</td><td>8.3</td></tr>
<tr><td>40W≤P<70W</td><td>15.0</td><td>11.4</td></tr>
<tr><td>70W≤P<150W</td><td>17.4</td><td>13.2</td></tr>
</table>

Remark
1. Minimum Energy Performance Standard (MEPS) applied and prohibited the production and sales of products that fall below the 5th grade, as defined below.
2. Target Energy Performance Standard (TEPS) is targeted to become the standard for MEPS in 2013 to accelerate improvement of GLS lamps efficiency in Korea.
<table>
<tr><th>R</th><th>Level</th></tr>
<tr><td>R ≤ 1.00</td><td>1</td></tr>
<tr><td>1.00 < R ≤ 1.10</td><td>2</td></tr>
<tr><td>1.10 < R ≤ 1.20</td><td>3</td></tr>
<tr><td>1.20 < R ≤ 1.30</td><td>4</td></tr>
<tr><td>1.30 < R ≤ 1.35</td><td>5</td></tr>
</table>
Where R = TEPS / Measured Efficacy (lm/W)</td><td></td></tr>
</table>

<table>
<tr><th>Country</th><th>Phasing Out</th><th>Control Scheme</th><th>Effective Date</th><th>Covered Lamp Types</th><th>Excluded Lamp Types</th><th>Remark</th></tr>
<tr><td>Philippine</td><td>Proposed Mandatory MEPS

for Non-reflector tungsten filament and halogen Incand-escent lamps for domestic and similar general lighting purposes</td><td>Philippine National Standard CDPNS 2050-6: 2008

Lamp and related equipment – Energy performance requirements – Part 6: Incandescent lamps for domestic and similar general lighting purposes</td><td>The draft standard has been circulated to various stakeholders for review and comments by the Government.</td><td>1. For all incandescent lamps includes both tungsten filament and tungsten halogen.
2. Lamp life not less than 2000 hrs
3. Lumen maintenance at least 80% at 75% rated life
4. Tested at 230V and 60Hz
5. Efficiency Requirement
<table><tr><th>Wattage</th><th>(lumens per watt)</th></tr><tr><td>≤ 25</td><td>12</td></tr><tr><td>>25 – 40</td><td>14</td></tr><tr><td>>40 – 60</td><td>15</td></tr><tr><td>>60 – 75</td><td>16</td></tr><tr><td>>75 – 100</td><td>17</td></tr><tr><td>>100</td><td>18</td></tr></table></td><td>Lamps intended to be used for medical, agricultural and other special purposes are excluded.</td><td>(Source: Department of Energy of Philippines Government)</td></tr>
</table>

Country	Phasing Out	Control Scheme	Effective Date	Covered Lamp Types [1&2]	Excluded Lamp Types [1&2]	Remark
USA	**GLS Incandescent Lamps**	Energy Independence and Security Act of 2007, Section 321 Energy Efficiency Standard for **GLS Lamp**	For General Service Incandescent lamps (GLS) Lumen / Max. W / Effective Date 1490 – 2600 lm, 72, 1/1/2012 1050 – 1489 lm, 53, 1/1/2013 750 – 1049 lm, 43, 1/1/2014 310 – 749lm, 29, 1/1/2014 For Modified Spectrum Lumen / Max. W / Effective Date 1118 – 1950 lm, 72, 1/1/2012 788 – 1117 lm, 53, 1/1/2013 563 – 787 lm, 43, 1/1/2014 232 – 562 lm, 29, 1/1/2014	General service incandescent lamp means a standard incandescent or halogen type lamp that (a) is intended for general service applications; (b) medium screw base; (c) lumen range 310 to 2,600 lm (~40 to 100W); and (d) voltage range within 110V and 130V (e) min. life 1000 hrs (f) CRI > 0.8 Efficiency requirement as per the adjacent lumen bin table	1. Lamp Types: appliance lamp, blacklight lamp, bug lamp, colored lamp, infrared lamp, left-hand thread lamp, marine lamp, marine signal service lamp, mine service lamp, plant lamp, reflector lamp, rough service lamp, shatter-resistant/shatter-proof/shatter-protected lamp, sign service lamp, silver bowl lamp, showcase lamp, 3-way Incandescent lamp, traffic signal lamp, vibration service lamp, G-shape with a diameter of 5 inches or more, T-shape lamp of 40 watts or less and a length of greater than 10 inches; B, BA, CA, F, G16-1/2, G25, G30, S, or M14 lamp of 40 watts or less. 2. Section 321 also sets a maximum wattage of 60 watts for candelabra base incandescent lamps, and 40 watts for intermediate base incandescent lamps.	1. The act has become legislative law in the federal government and will be further enacted by individual state 2. DOE is authorized to monitor the progress and monitor sales of these exempted lamps between 2010 and 2025 and impose regulations

Country	***Phasing Out***	***Control Scheme***	***Effective Date***	***Covered Lamp Types*** [1&2]	***Excluded Lamp Types*** [1&2]	***Remark***
USA	**Incandescent Reflector Lamps**	MEPS Scheme under the Section 322 Energy Efficiency Standard for **Incandescent Reflector Lamps**	1. BR, ER and BPAR lamps and similar shapes, on and after 1/1/2008 2. Reflector lamps between 2.25-2.75 inches, on or after 6/16/2008	1. The 1992 legislation has already covered R and PAR lamps greater than 2.75 inches in diameter, medium screw base, 40-205 watts, 115-130 volts. 2. The new act include additional lamps include BR, ER, and BPAR 3. Efficiency Requirement Wattage (lumens per watt) 40 – 50 10.5 51 – 66 11.0 67 – 85 12.5 86 – 115 14.0 116 – 155 14.5 156 – 205 15.0	1. BR30, BR40 and ER40 lamps rated at 65 watts 2. ER30, BR30, BR40 and ER40 lamps rated at ≤ 50 watts 3. R20 lamps rated at ≤45 watts	Manufacturers can continue to make and sell 65BR30 lamps.

Country	***Phasing Out***	***MEPS Scheme***	***Effective Date***	***Covered Lamp Types***	***Excluded Lamp Types***	***Remark***
Cuba	GLS Incandescent Lamps.	Banning of Import and sale of incandescent lamp with free of charge replacement of Incandescent lamp for citizen	Cuba Government has offered one to one CFL to incandescent lamp free replacement for its citizens. By 2007, they have already replaced 116 million incandescent light bulbs. Since then they have stopped the importation and sale of incandescent lamps in the Cuba	General Lighting Service Incandescent Lamps As an effort to reduce imports of expensive (fossil) fuels, Fidel Castro himself decided that in Cuba all incandescent lamps should be replaced by more efficient fluorescent lamps. Inefficient incandescent lamps need to be phased out and substituted with existing (or new) energy-efficient alternatives, including compact fluorescent lamps (CFLs), Energy-saving halogen lamps and LED lamps.	Only for the GLS lamps that can be replaced by CFL	
Ghana	GLS Incandescent Lamps.	Banning of Import and sale of incandescent lamp with free of charge replacement of Incandescent GLS lamp for citizen	Anticipated 2008, subject to the legislation in Parliament There were 6 million CFL provided for free in 2007	General Lighting Service Incandescent Lamps	No Details of Ghana Information	

<table>
<tr><th>Country</th><th>Phasing Out</th><th>Control Scheme</th><th>Programme Schedule</th><th>Covered Lamp Types</th><th>Excluded Lamp Types</th><th>Remark</th></tr>
<tr><td>EU</td><td>Non-reflector GLS and tungsten filament incandescent lamps and inefficient halogen lamps</td><td>European Commission for phasing out electric filament lamps, as well as all low performance lamps.</td><td>The schedule for the phasing out of incandescent bulbs as approved in the EU new directive has commenced since September 2009. The regulation applies to non-directional lamps. Directional (reflector) lamps are now being studied for coverage under separate and dedicated measure at the end of 2009 or in 2010.

Incandescent lamps will be phased out from the EU market starting in 2009 and finishing in 2012.
<table>
<tr><td></td><td colspan="4">Non-clear lamps</td><td colspan="7">Clear lamps</td></tr>
<tr><td>Date</td><td>Requirement</td><td>Incandescent</td><td>All Halogen</td><td>CFLs</td><td>Requirement</td><td colspan="4">Incandescent / Conventional halogen</td><td>Halogen C</td><td>Halogen B</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>≧100 W</td><td>≧ 75 W</td><td>≧60 W</td><td>60W ></td><td></td><td></td></tr>
<tr><td>Today</td><td>None</td><td></td><td></td><td></td><td>None</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sept 2009</td><td>A</td><td></td><td></td><td></td><td>C for ≧100W, E for the rest [1]</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sept 2010</td><td>A</td><td></td><td></td><td></td><td>C for ≧75W</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sept 2011</td><td>A</td><td></td><td></td><td></td><td>C for ≧60W</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sept 2012</td><td>A</td><td></td><td></td><td></td><td>C for all</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sept 2013</td><td colspan="11">Second level of functionality requirements</td></tr>
<tr><td>Review 2014</td><td colspan="11">Review</td></tr>
<tr><td>Sept 2016</td><td>A</td><td></td><td></td><td></td><td></td><td>B/C[2]</td><td></td><td></td><td></td><td>[3]</td><td></td></tr>
</table>
[1] The requirement is raised for all clear lamps to class E, phasing out F and G class incandescent and halogen lamps in all wattages already in September 2009. After the first stage, only E-class incandescent lamps remain available in some wattage until they are also gradually phased out by September 2012.
[2] Special cap halogen lamps will be required to be at least class C, all other clear lamps will have to be at least Class B.
[3] Only special cap halogen lamps are allowed to be C-class.</td><td>General Lighting Service Incandescent Lamps and Halogen Lamp</td><td>Has yet to be determined by the EU Commission</td><td></td></tr>
</table>

Country	***Phasing Out***	***Control Scheme***	***Programme Schedule***	***Covered Lamp Types***	***Excluded Lamp Types***	***Remark***
			The grey cell indicates that the lamp category given in the column header is still available in the particular stage. The capitalized letters refer to energy classes defined for the lamp energy label (Directive 98/11/EC). CFL = compact fluorescent lamp			

Lamps shall be classified in class A if:

$$W \leq 0{,}24\ \sqrt{\Phi} + 0{,}0103\ \Phi$$

where Φ is the lumen output of the lamp
where W is the power input into the lamp in watts.

If a lamp is not classified in class A, a reference wattage W_R shall be calculated as follows:

$$W_R = 0{,}88\ \sqrt{\Phi} + 0{,}049\ \Phi, \text{ when } \Phi > 34 \text{ lumens}$$
$$0{,}2\ \Phi, \qquad \text{when } \Phi \leq 34 \text{ lumens}$$

where Φ is the lumen output of the lamp.

An energy efficiency index E_I is then set as

$$E_I = \frac{W}{W_R}$$

where W is the power input into the lamp in watts.

The energy efficiency classes are then set in accordance with the following table:

Energy efficiency class	Energy efficiency index E_I
B	$E_I < 60\ \%$
C	$60\ \% \leq E_I < 80\ \%$
D	$80\ \% \leq E_I < 95\ \%$
E	$95\ \% \leq E_I < 110\ \%$
F	$110\ \% \leq E_I < 130\ \%$
G	$E_I \geq 130\ \%$

Table 2.2(b) Comparison Table for Voluntary Schemes

Country	***Voluntary Program***	***Organiser***	***Program Details***	***Coverage Regarding Incandescent Lamp***	***Status***	***Remark***
Thailand	Phase I: 1996 -1998 • Bulk purchase program in 1996	Electricity Generating Authority of Thailand (EGAT)	1. Achieved low price on CFLs by bulk purchasing and reselling at cost. 2. Stimulated customer demand for CFLs by launching public campaign 3. Marketed through 7-11 convenience stores only	Promotion of low cost CFL to general public to replace GLS incandescent lamp	Reason to stop program in 1998 1. Upset regular lighting retailers 2. Only 1-2 manufacturers could participated 3. Consumers don't shop for lamps at 7-11s 4. Introducing of inexpensive low-quality CFLs in the market decreased the customer's confidence	(Source: DSM office of EGAT)
	Phase II: 1999 until now • Labeling program since 1999	Electricity Generating Authority of Thailand (EGAT)	1. Open to all supplier 2. Endorsement label 3. Testing of lifetime and quality 4. Distribute the no.5 label to high efficiency CFLs passing TISI (Thai Industrial Standard Institute) test.	Promotion of qualified CFL to the general public	Continued running until now	
	Phase III: 2007-2010 • CFL give-away and half-market price CFLs program since 2007	Electricity Generating Authority of Thailand (EGAT)	1. In 2007, Thai Minister of Energy (Dr. Piyasvasti Amranand) announced on 21st of March plans for a national campaign to subsidize the sale of energy-saving compact fluorescent lamps (CFLs) and work with Thai suppliers to phase out the sale of incandescent lamps 2. Thai government through Energy Conservation Fund provided a THB 50 million (US$ 2.0 million) fund for EGAT to implement the program to reduce the cost of CFLs 3. 800,000 CFLs give-away to consumers and public 4. Selling of EGAT branding half-market price CFLs	DSM type program to promote CFL to phase out the sale of incandescent lamp	Under implementation	
	Consideration of MEPS	Not known yet	It's estimated MEPS for CFLs would come into action within 2010, the year that Thailand plan to reach its goal of phasing out the incandescent lamps usage throughout the country.	Not known yet	Not known yet	

Country	***Voluntary Program***	***Organiser***	***Program Details***	***Coverage Regarding Incandescent***	***Status***	***Remark***
Japan	4 proposal of Energy Saving by Lamp Replacement announced in Dec, 2006	Japan Electric Lamp Manufacturers Association (JELMA)	The 4 proposals 1. incandescent lamps to CFLi 2. tungsten halogen to compact fluorescent lamps and ceramic metal halide lamps; 3. fluorescent lamps to Hf-type lamps (High Frequency Operating type); and 4. high pressure mercury lamps to metal halide and high pressure sodium lamps.	The initial news about the policy is that the incandescent lamps are divided into two groups: **<u>Group A</u>** E26 base lamps for general lighting ● with a target that 70% of Group A will be replaced to CFLi) (e.g. , usual lamp and ball lamp) ● remained used for dimming, spot lighting and decoration **<u>Group B</u>** Lamps for special lighting uses (remained) e.g. reflector lamp, beam type, coloured lamp, shockproof type, mini-krypton type, miniature lamp etc. CFLi – compact fluorescent lamp with integrated ballast	Government and lamp manufacturers made stronger sales promotion for CFL. Annual Growth on the sales of CFL up 22% in 2007	The Tokyo Metropolitan Government (TMG) announced on September 21, 2007, that it works with local retailers such as convenience stores, supermarkets and appliance stores to promote compact light bulbs. The effort is part of TMG's efforts to step up its campaign to eliminate incandescent light bulbs under its Climate Change Strategy, which calls on citizens to switch from incandescent to energy-efficient fluorescent bulbs in order to save more energy in home
	Mr. Amari, minister of METI announced “ the replacement policy for incandescent to CFLi”	Ministry of Economy, Trade and Industry (METI) of Japan	Minister of Economy, Trade and Industry Akira Amari said “by 2012, all of Japan should be using energy-saving fluorescent bulbs rather than incandescent bulbs as part of the effort to cut greenhouse gas emissions”. Amari said the move will "not be obligatory" but added he will urge industry to improve the performance of fluorescent bulbs. Japan is currently facing difficulty in meeting its goal for reducing greenhouse gas emissions under the Kyoto Protocol, which calls on this nation to slash emissions by 6 percent by fiscal 2008-2012 from their fiscal 1990 levels. Therefore, it is taken into consideration the end of the Kyoto commitment period in deciding the target year for making the transition to fluorescent. The government has already been promoting fluorescent bulbs, but only 24 million were sold in 2006, compared with 135 million incandescent bulbs, according to the Japan Electric Lamp Manufacturers Association.		Some of Lamp manufacturers announced their target time of their full replacement from incandescent to CFLi by 2010.	

Country	***Voluntary Program***	***Organiser***	***Program Details***	***Lamp Types Covered***	***Status***	***Remark***
United Kingdom	Voluntary Phase Out Incandescent Lamps Programme	Led by UK retailers and suppliers, coordinated by Energy Saving Trust and Department of Environment, Food and Affair (DEFRA)	The UK voluntary phase out schedule • By January 2008 retailers will cease to replenish stocks of inefficient GLS lamps 150W and above. • By January 2009 retailers will cease to replenish stocks of inefficient GLS lamps 100W and above. • By January 2010 retailers will cease to replenish stocks of inefficient GLS lamps 60W and above. • By January 2011 retailers will cease to replenish stocks of all remaining inefficient GLS lamps and 60W candle and golf ball lamps. • By 31st December 2011 retailers will cease selling all remaining inefficient GLS lamps and 60W candle and golf ball lamps	General Lighting Service Incandescent Lamps	Some retailers have completely stop selling incandescent lamps	Aims to allow UK to continue to lead Europe and make carbon savings in advance of EuP measures

Reference Remark:

1. (a) Common Lamp Type definition:

(i) Non-reflector Lamp

1. General Lighting Service Lamp Types
- Standard GLS (A), Mushroom can emit light evenly (nearly) in all directions
- Pear-shaped (PS)

2. Other Tungsten Filament Lamp Types:
- Flame (F)
- Twisted Candle, Bent-tip Candle (CA & BA)
- Candle (B)
- Globe (G)
- Fancy Round (P)

3. Halogen Lamp Types:
- Main Voltage Halogen
- Main Voltage Halogen A Shape
- ELV Halogen

(ii) Reflector Lamp

1. Tungsten Filament Reflector Lamp Types
- Standard Reflector (R) - Reflective coating inside the bulb directs light forward
- Elliptical Reflector (ER) – with ellipitical shape
- Bulged Reflectors (BR) – with bulged shape
- Flood types (FL) spread light over a confined area
- Parabolic Aluminized Reflector (PAR) bulbs control light more precisely and produce about four times the concentrated light intensity of General Service (A), 120V Sizes:PAR 16, 20, 30, 38, 56 and 64. 230V Sizes: Par 38, 56 and 64. Brown Parabolic Aluminized Reflector (BPAR) which is also a PAR lamp, but the glass bulb is formed as one piece (i.e., blown)

2. Halogen Reflector Lamp Types
- Main Voltage Halogen
- ELV Halogen

(b) Common Screw Thread Lamp Base Definition

In each designation, the E stands for Edison, who created the screw-base lamp, and the number is the diameter of the screw base in millimeters. (Whereas in North America the designations for the bulb glass diameter are in eighths of an inch.) There are four common sizes of screw-in sockets used for line-voltage lamps:
- candelabra: E12 North America, E10 & E11 in Europe
- intermediate: E17 North America, E14 (SmallES) in Europe
- medium or standard: E26 (MES) in North America, E27 (ES) in Europe
- mogul: E39 North America, E40 (GoliathES) in Europe.

Other screw thread sizes include "admedium" size (E29), larger than common lamp sockets, intended to frustrate thieves of bulbs used in public places;

- miniature size (E5) generally used only for low-voltage applications such as with a battery.

2. (i) Non-Reflector Lamp

1. General Lighting Service Lamp (GLS) **[29]**

	
Standard GLS (A)	Pear Shape (PS)

2. Other Tungsten Filament Lamp**[29]**

				
Flame (F)	Twisted Candle, Bent-tip Candle (CA & BA)	Candle (B)	Globe (G)	Fancy Round (P)

3. Halogen Lamp**[29]**

 		
Main Voltage Halogen	Main Voltage Halogen A Shape	Low Voltage Halogen

(ii) Reflector Lamp[29]

1. Tungsten Filament Reflector Lamp

				
Standard Reflector (R)	Elliptical Reflector (ER)	Bulged (BR) Reflector	Flood types (FL) spread light	PAR and BPAR

2. Halogen Reflector Lamp

	
Main Voltage Halogen	Low Voltage Halogen Reflector

2.3 Summary of MEPS Schemes of Australia, USA, Canada, EU, Korea and Philippines

Generally speaking, the commonly adopted approach for the phasing out of incandescent lamps is to enforce legislative requirements on the minimum energy performance standard for the incandescent lamps. Major countries territories including Australia, USA, Canada, EU, Korea and Philippines have developed the minimum energy efficiency standard for the purpose of setting out the phasing out scheme for the incandescent lamp. Table 2.3 (a) shows the types of incandescent lamps being covered in the MEPS scheme as adopted in these countries.

Table 2.3 (a) - Lamp Types Included in MEPS Schemes for Major Countries

Country	Non-Reflector				Reflector	
	GLS	Other Tungsten Filament	Main Volt Halogen	ELV Halogen	All Tungsten Filament	Halogen (Main and Extra Low Voltage)
EU 27 Countries	✓	✓	✓	✓	x	x
USA / Canada	✓	✓	✓	x	✓	x
Australia	✓	✓	✓	✓	✓	✓
Philippines	✓	✓	✓	x	x	x
Korea	✓	x	x	x	x	x

The three most popular types of lamps as covered in the MEPS scheme of these countries are non-reflector type incandescent lamps which include GLS lamps, non-reflector tungsten filament lamps and non-reflector main voltage halogen lamps. Reflector type incandescent lamps are only covered in the MEPS schemes of Australia, Canada and USA.

Voluntary programs such as the giving of incentive to encourage customers to buy and replace GLS lamps and non-reflector tungsten filament lamps with compatible compact fluorescent lamps (CFL) as adopted in Thailand, making agreements with retailers and manufacturers in switching the supply of CFLs in the market as adopted in Japan and UK, etc. All these voluntary programmes may also bring immediate benefits to the countries in lowering the penetration rate of inefficient incandescent lamps and reduce energy consumption.

One interesting observation worth mentioning is New Zealand as it declares in February 2009 that there is no plan to introduce regulatory requirements through MEPS in phasing out incandescent lamps. The original MEPS of New Zealand benchmarks closely with Australia's standard and was intended to be effective in middle of 2009.

All these findings point to the fact that the issue of phasing out incandescent lamps are not straight forward and needs very detailed consideration of local situations and overseas countries' schemes could not be simply replicated in other countries.

The overview and summary tables for the MEPS schemes of these countries are provided in Table 2.3(b) for non-reflector type incandescent lamp and in Table 2.3(c) for reflector type respectively.

Table 2.3 (b) Summary Table for MEPS Scheme for Non-reflector Lamps

Country	Australia	United States	Canada	EU	Korea	Philippines
Phasing Out Scheme						
Mandatory/Voluntary	Mandatory MEPS	Mandatory MEPS	Mandatory MEPS	Mandatory MEPS	Mandatory (Energy Efficiency Label, E-Standby Programs) + Voluntary (High Efficiency Certification, E-Standby Programs)	Proposed Mandatory MEPS, Announced to phase out in 2010, and seeking financial support from Asian Development Bank.
Details of Phasing Out Programme						
Covered Products						
a. General Lighting Service (GLS) Lamps	Yes	Yes	Yes	Yes	Yes (by energy efficiency label, MEPS)	Yes
b. Other Tungsten Filament Lamps including Candle-shaped, fancy round and decorative Lamps	Yes	Yes	Yes	Yes	N.A.	Yes
c. Mains Voltage Halogen Non-reflector Lamp	Yes	Yes	Yes	Yes	N.A.	Yes
d. Extra Low Voltage (ELV) Halogen non-reflector Lamps	Yes	N.A.	N.A.	Yes	N.A.	No
e. Others (please specify)	CFLs and ELV converters for ELV lamps	Fluorescent Lamps	N.A.	N.A	N.A.	Lamps intended to be used for medical, agricultural and other special purposes are excluded.
Implementation Programme						
2009	(i) General lamp service (GLS) (ii) Extra low voltage (ELV) halogen non-reflector lamps	N/A	N/A	Clear Lamp (i) All non-directional incandescent lamp (ii) Lamp's equivalent lighting output $\geq$ 100W incandescent bulbs must meet C-class standard, remaining must meet E-class standard (iii) All Lower wattage incandescent lamps of the F and G class will be phased out Non-clear Lamp (i) All non-directional incandescent lamp (ii) must meet A-class standard	MEPS for Incandescent Lamps, effective 1/1/2009	N/A
Restriction on Import	for (i) 1/2/2009 for (ii) N/A and for retail restriction only	N/A	N/A	September 2009	January 2008	N/A
Restriction on Sale	November 2009 (tentative)	N/A	N/A	September 2009	January 2009	N/A

Country	Australia	United States	Canada	EU	Korea	Philippines
2010	(i) >40W candle, fancy round & decorative lamps (ii) Main voltage halogen non-reflector (iii) ELVC (not subject to import restriction)	N/A	N/A	<u>Clear Lamp</u> (i) All non-directional incandescent lamp (ii) Lamp's equivalent lighting output $\geq$ 75W incandescent bulbs must meet C-class standard, remaining must meet E-class standard (iii) All Lower wattage incandescent lamps of the F and G class will be phased out <u>Non-clear Lamp</u> (i) All non-directional incandescent lamp (ii) must meet A-class standard	N/A	1. For all incandescent lamps includes both tungsten filament and tungsten halogen. 2. Lamp life not less than 2000 hrs 3. Lumen maintenance at least 80% at 75% rated life 4. Tested at 230V and 60V
Restriction on Import	November 2009 (tentative)	N/A	N/A	September 2010	N/A	2010 (tentative)
Restriction on Sale/Retail	November 2010 (tentative)	N/A	N/A	September 2010	N/A	2010 (tentative)
2011	N/A	N/A	N/A	<u>Clear Lamp</u> (i) All non-directional incandescent lamp (ii) Lamp's equivalent lighting output $\geq$ 60W incandescent bulbs must meet C-class standard, remaining must meet E-class standard (iii) All Lower wattage incandescent lamps of the F and G class will be phased out <u>Non-clear Lamp</u> (i) All non-directional incandescent lamp (ii) must meet A-class standard	N/A	N/A
Restriction on Import	N/A	N/A	N/A	September 2011	N/A	N/A
Restriction on Sale	N/A	N/A	N/A	September 2011	N/A	N/A
2012	(i) Mains voltage reflector lamps including halogen (PAR, ER, R, etc.) (ii)>25W candle, fancy round & decorative lamps	Lamps of wattage 100W with rated lumens from 1490 - 2600 shall be reduced to 72W	GLS and GLS modified Spectrum (1050-2600 lm)	<u>Clear Lamp</u> (i) All non-directional incandescent lamp must meet C-class standard, <u>Non-clear Lamp</u> (i) All non-directional incandescent lamp (ii) must meet A-class standard	To set New MEPS as stated for Targeted Energy Performance Standard before 31/12/2012	N/A
Restriction on Import	November 2011 (tentative)	1 January 2012	1/1/2012	September 2012	December 2012	N/A
Restriction on Sale	November 2012 (tentative)	1 January 2012	1/1/2012	September 2012	December 2012	N/A
2013	N/A	Lamps of wattage 75W with rated lumens from 1050 -1489 shall be reduced to 53W	GLS and GLS modified Spectrum (250-1049 lm)	N/A	N/A	N/A
Restriction on Import	N/A	N.A.	31-Dec-12	N/A	N/A	N/A

<table>
<tr><th>Country</th><th>Australia</th><th>United States</th><th>Canada</th><th>EU</th><th>Korea</th><th>Philippines</th></tr>
<tr><td>Restriction on Sale</td><td>N/A</td><td>1 January 2013</td><td>31-Dec-12</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>2014</td><td>N/A</td><td>(i) Lamps of wattage 60W with rated lumens from 750 -1049 shall be reduced to 43W
(ii) Lamps of wattage 40W with rated lumens from 310 -749 shall be reduced to 29W</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Import</td><td>N/A</td><td>N.A.</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Sale</td><td>N/A</td><td>1 January 2014</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>2016</td><td>N/A</td><td>N/A</td><td>N/A</td><td><u>Clear Lamp</u>
(i) All non-directional incandescent lamp must meet B-class standard except for special cap halogen lamp is required to meet C-class standard
<u>Non-clear Lamp</u>
(i) All non-directional incandescent lamp
(ii) must meet A-class standard</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Import</td><td>N/A</td><td>N/A</td><td>N/A</td><td>September 2016</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Sale</td><td>N/A</td><td>N/A</td><td>N/A</td><td>September 2016</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="7">Criteria of Phasing Out Programme (Incandescent Lamps)</td></tr>
<tr><td>a. Minimum Energy Performance Standards (Yes/No)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>b. Testing Requirements/Standards for incandescent lamps</td><td>1. Test Standard AS/NZS 4931.1
2. MEPS AS/NZ 4931.2</td><td>10 CFR Part 430 Subpart B App R US Energy Star 10 CFR Part 430 Subpart B App W</td><td>IESNA LM45 for lamp lumen output and wattage
IESNA LM49 for lamp life
CIE 13.3 for lamp Colour Rendering Index (CRI) (tested at 120 volts regardless of its nominal voltage)</td><td>Under Development</td><td>Yes (KS C 7501-99)</td><td>Philippine National Standard CDPNS 2050-6: 2008</td></tr>
<tr><td>c. Minimum Efficacy Requirements for incandescent lamps</td><td>Initial efficacy ≥ 2.8 * ln(initial lumens) – 4.0</td><td>For General Service Incandescent lamps (GSL)
<table>
<tr><th>Lumen</th><th>Max. W</th><th>Effective Date</th></tr>
<tr><td>1490 – 2600</td><td>72</td><td>1/1/2012</td></tr>
<tr><td>1050 – 1489</td><td>53</td><td>1/1/2013</td></tr>
<tr><td>750 – 1049</td><td>43</td><td>1/1/2014</td></tr>
<tr><td>310 – 749</td><td>29</td><td>1/1/2014</td></tr>
</table>
For Modified Spectrum
<table>
<tr><th>Lumen</th><th>Max. W</th><th>Effective Date</th></tr>
<tr><td>1118 – 1950</td><td>72</td><td>1/1/2012</td></tr>
<tr><td>788 – 1117</td><td>53</td><td>1/1/2013</td></tr>
<tr><td>563 – 787</td><td>43</td><td>1/1/2014</td></tr>
<tr><td>232 – 562</td><td>29</td><td>1/1/2014</td></tr>
</table></td><td>For GLS Efficiency Requirement - Efficacy Curve :
>=4.0357 x ln(lumen output) – 7.1345

For Modified Spectrum Efficiency Requirement - 0.75 x GLS Efficiency Requirement

For Reflector lamps,
<table>
<tr><th>Rated Wattage</th><th>Min. Average Lamp Efficacy (lm/W)</th></tr>
<tr><td>40-50</td><td>10.5</td></tr>
<tr><td>51-66</td><td>11.0</td></tr>
<tr><td>67-85</td><td>12.5</td></tr>
<tr><td>86-115</td><td>14.0</td></tr>
<tr><td>116-155</td><td>14.5</td></tr>
<tr><td>156-205</td><td>15.0</td></tr>
</table></td><td>1. The requirement is raised for all clear lamps to class E, phasing out F and G class incandescent and halogen lamps in all wattages already in September 2009. After the first stage, only E-class incandescent lamps remain available in some wattage until they are also gradually phased out by September 2012.
2. Special cap halogen lamps will be required to be at least class C, all other clear lamps will have to be at least Class B.</td><td>
<table>
<tr><th>Rated Lamp Wattage</th><th>TEPS (lm/W)</th><th>MEPS (lm/W)</th></tr>
<tr><td>25W≦P<40W</td><td>10.9</td><td>8.3</td></tr>
<tr><td>40W≦P<70W</td><td>15.0</td><td>11.4</td></tr>
<tr><td>70W≦P<150W</td><td>17.4</td><td>13.2</td></tr>
</table>
TEPS effective till 31/12/2012
MEPS effective from 1/1/2009</td><td>
<table>
<tr><th>Wattage</th><th>Lumens per Watt</th></tr>
<tr><td>≤ 25</td><td>12</td></tr>
<tr><td>>25-40</td><td>14</td></tr>
<tr><td>>40-60</td><td>15</td></tr>
<tr><td>>60-75</td><td>16</td></tr>
<tr><td>>75-100</td><td>17</td></tr>
<tr><td>>100</td><td>18</td></tr>
</table></td></tr>
</table>

Country	Australia	United States	Canada	EU	Korea	Philippines
d. Efficacy (Lumens/Watt) for a 900 lumen incandescent lamps (900 lumens is approximately the amount of light emitted by a common 60 Watt light bulb)	15 (lm/Watt)	21 (lm/Watt)	20.3	15.2	11.4	15
Criteria of Phasing Out Programme (Poor Quality CFL)						
a. Minimum Energy Performance Standards (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes
b. Testing Requirements/Standards for CFL	AS/NZS 4934.1	10 CFR Part 430 Subpart B App R US Energy Star 10 CFR Part 430 Subpart B App W	CAN/CSA-C 861-95	Under Development	Yes (KS C 7621-99)	Yes (PNS 603-2-Amd.1:2001)
c. Minimum Efficacy Requirements for CFL	AS/NZS 4934.2	N/A	N/A	N/A	Yes	Yes
Conformity Assessment by Suppliers						
a. Testing by accredited testing laboratory (Yes/No)	no available testing lab information at this stage	No	No	No	Yes	subject to further announcement
b. Self-declaration by the supplier (Yes/No)	Yes	Yes	Yes	Yes	Yes	no
Legislation (For mandatory scheme)						
Name of Act/Ordinance/Regulation	Minimum Energy performance Standard for Incandescent Lamps	Energy Independence and Security Act of 2007	Canada's Energy Efficiency Act	EU Directive on Incandescent Lamps	Regulations on Energy Efficiency Labelling and Standards	Minimum Efficiency Standard for Lamp
Legislative Framework						
a. Pre-market Approval/Registration	Yes	Yes	Yes	No	Yes	subject to further announcement
b. Post-market	N/A	N/A	N/A	Yes	N/A	subject to further announcement
c. Label affixed to the packaging (Yes/No)	Yes	Yes	Yes	Yes	Yes	subject to further announcement
Enforcement Agency/Department						
a. Name of agency/department	- National Appliance and Equipment Energy Efficiency Committee(NAEEEC)	Federal Energy Regulatory Commission	Natural Resources Canada	European Commission (EC)	MKE, Korea Energy Management Corporation (KEMCO) of Ministry of Knowledge Economy (MKE)	Department of Energy of Philippines Government
b. Others	- The Ministerial Council on Energy (MCE)					N.A
Enforcement Strategies						
a. Inspection at Customs Points	Yes	Yes	Yes	No	KEMCO	subject to further announcement
b. Inspection at Retail Points	Yes	N/A	N/A	Yes	N/A	subject to further announcement
c. Compliance Testing by accredited testing laboratory	no available testing lab information at this stage	Yes	Yes	No	Yes	subject to further announcement

Table 2.3 (c) Summary Table for MEPS Scheme for Reflector Lamps

<table>
<tr><th>Country</th><th>Australia</th><th>United States</th><th>Canada</th></tr>
<tr><td colspan="4">Phasing Out Scheme</td></tr>
<tr><td>Mandatory/Voluntary</td><td>Mandatory (pending for legislation)</td><td>Mandatory</td><td>Mandatory (pending for passing of Part II Gazette)</td></tr>
<tr><td colspan="4">Details of Phasing Out Programme</td></tr>
<tr><td>Covered Products</td><td></td><td></td><td></td></tr>
<tr><td>a Mains Voltage Reflector Lamp</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>b. Extra Low Voltage (ELV) Halogen Reflector Lamps</td><td>Yes</td><td>N.A.</td><td>N.A.</td></tr>
<tr><td>g. Others (please specify)</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="4">Implementation Programme</td></tr>
<tr><td>2009</td><td>ELV halogen, reflector</td><td>General Service Reflector Lamp</td><td>General Service Reflector Lamp</td></tr>
<tr><td>Restriction on Import</td><td>November 2009 (tentative)</td><td>Most states started from 1 January 2009</td><td>subject to the Part II Gazaett Publication originally scheduled in May 2009</td></tr>
<tr><td>Restriction on Sale</td><td>November 2010 (tentative)</td><td>Most states started from 1 January 2009</td><td>subject to the Part II Gazaett Publication originally scheduled in May 2010</td></tr>
<tr><td>2010</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Import</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Sale/Retail</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>2011</td><td>Main voltage reflector lamps include halogen</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Import</td><td>November 2011 (tentative)</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Restriction on Sale/Retail</td><td>November 2012 (tentative)</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="4">Criteria of Phasing Out Programme (Incandescent Lamps)</td></tr>
<tr><td>a. Minimum Energy Performance Standards (Yes/No)</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>b. Testing Requirements/Standards for incandescent lamps</td><td>1. Test Standard AS/NZS 4931.1
2. MEPS AS/NZ 4931.2</td><td>conform to sections 4.2 and 5.0 of IESNA LM–20 (see 10 CFR 430.22)</td><td>CAN/CSA-C862-01 ANSI C78.21 Table 1 of Part II for lamp class</td></tr>
<tr><td>c. Minimum Efficacy Requirements</td><td>Initial efficacy $\geq$ 2.8 * ln(initial lumens) – 4.0 (Tentative)</td><td><table><tr><th>Wattage Range</th><th>Min. Lumens/ Watt</th></tr><tr><td>40-50</td><td>10.5</td></tr><tr><td>51-66</td><td>11.0</td></tr><tr><td>67-85</td><td>12.5</td></tr><tr><td>86-115</td><td>14.0</td></tr><tr><td>116-155</td><td>14.5</td></tr><tr><td>156-205</td><td>15.0</td></tr></table></td><td><table><tr><th>Wattage Range</th><th>Min. Lumens/ Watt</th></tr><tr><td>40-50</td><td>10.5</td></tr><tr><td>51-66</td><td>11.0</td></tr><tr><td>67-85</td><td>12.5</td></tr><tr><td>86-115</td><td>14.0</td></tr><tr><td>116-155</td><td>14.5</td></tr><tr><td>156-205</td><td>15.0</td></tr></table></td></tr>
<tr><td>d. Efficacy (Lumens/Watt) for a 900 lumen incandescent lamps (900 lumens is approximately the amount of light emitted by a</td><td>15</td><td>11</td><td>11</td></tr>
</table>

Country	Australia	United States	Canada
common 60 Watt light bulb)			
Criteria of Phasing Out Programme (Poor Quality CFL)			
a. Minimum Energy Performance Standards (Yes/No)	Yes	Yes	Yes
b. Testing Requirements/Standards for CFL	AS/NZS 4934.1	conform to sections 4.2 and 5.0 of IESNA LM–20 (see 10 CFR 430.22)	CAN/CSA-C 861-95
c. Minimum Efficacy Requirements for CFL	AS/NZS 4934.2	N.A.	N.A.
Conformity Assessment by Suppliers			
a. Testing by accredited testing laboratory (Yes/No)	Yes	No	No
b. Self-declaration by the supplier (Yes/No)	No	Yes	Yes
Legislation (For mandatory scheme)			
Name of Act/Ordinance/Regulation	Minimum Energy performance Standard for Incandescent Lamps	Energy Independence and Security Act of 2007	Canada's Energy Efficiency Act
Legislative Framework			
a. Pre-market Approval/Registration	Yes	Yes	Yes
b. Post-market	No	No	No
c. Label affixed to the packaging (Yes/No)	Yes	Yes	Yes
Enforcement Agency/Department			
a. Name of agency/department	- National Appliance and Equipment Energy Efficiency Committee(NAEEEC)	Federal Energy Regulatory Commission	Natural Resources Canada
b. Others	- The Ministerial Council on Energy (MCE)		
Enforcement Strategies			
a. Inspection at Customs Points	Yes	Yes	Yes
b. Inspection at Retail Points	Yes	No	No
c. Compliance Testing by accredited testing laboratory	Yes	Yes	Yes

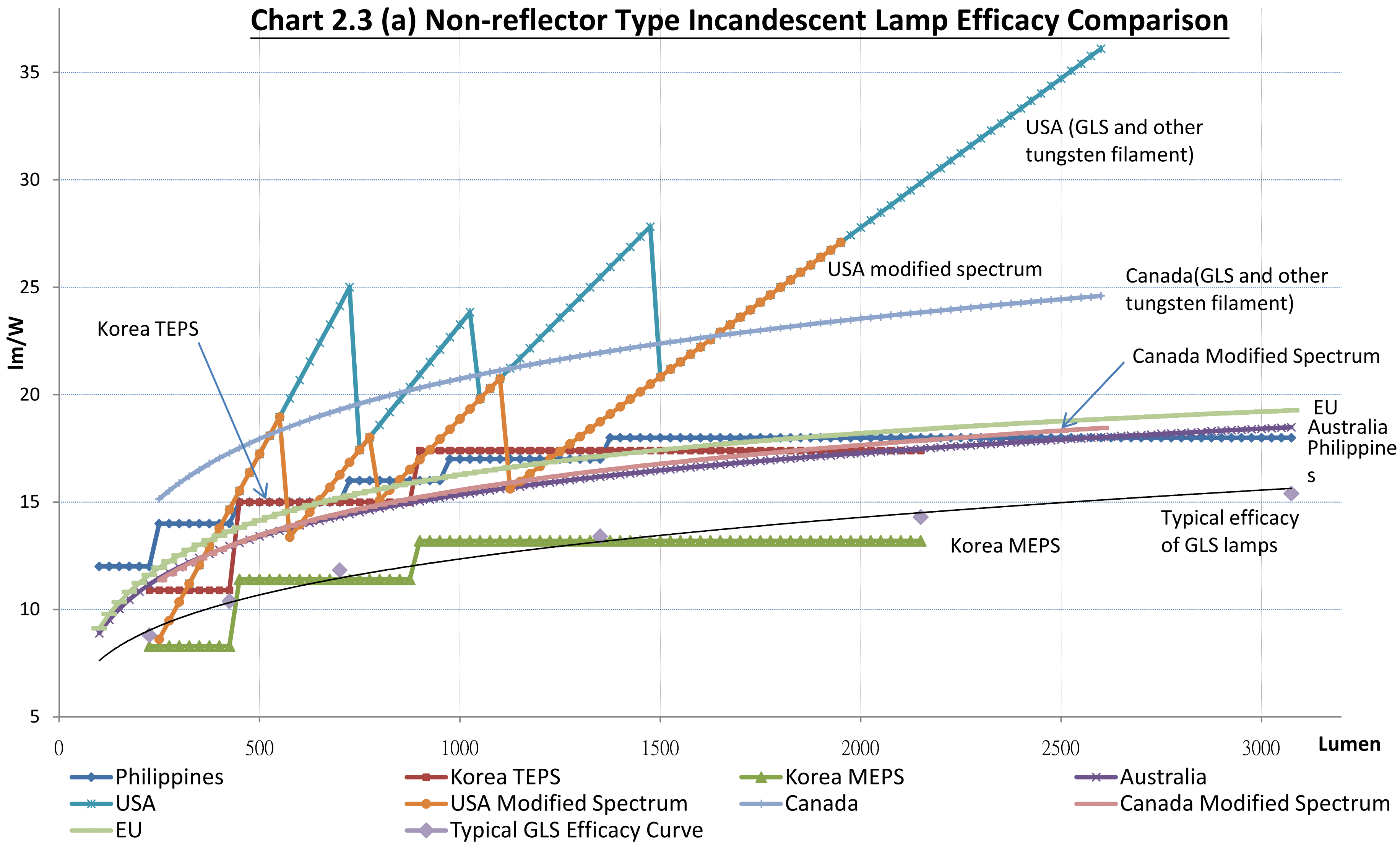


Chart 2.3 (a) Non-reflector Type Incandescent Lamp Efficacy Comparison
lm/W
Lumen
35
30
25
20
15
10
5
0
500
1000
1500
2000
2500
3000
USA (GLS and other tungsten filament)
USA modified spectrum
Canada(GLS and other tungsten filament)
Canada Modified Spectrum
Korea TEPS
EU
Australia
Philippines
Typical efficacy of GLS lamps
Korea MEPS
Philippines
Korea TEPS
Korea MEPS
Australia
USA
USA Modified Spectrum
Canada
Canada Modified Spectrum
EU
Typical GLS Efficacy Curve

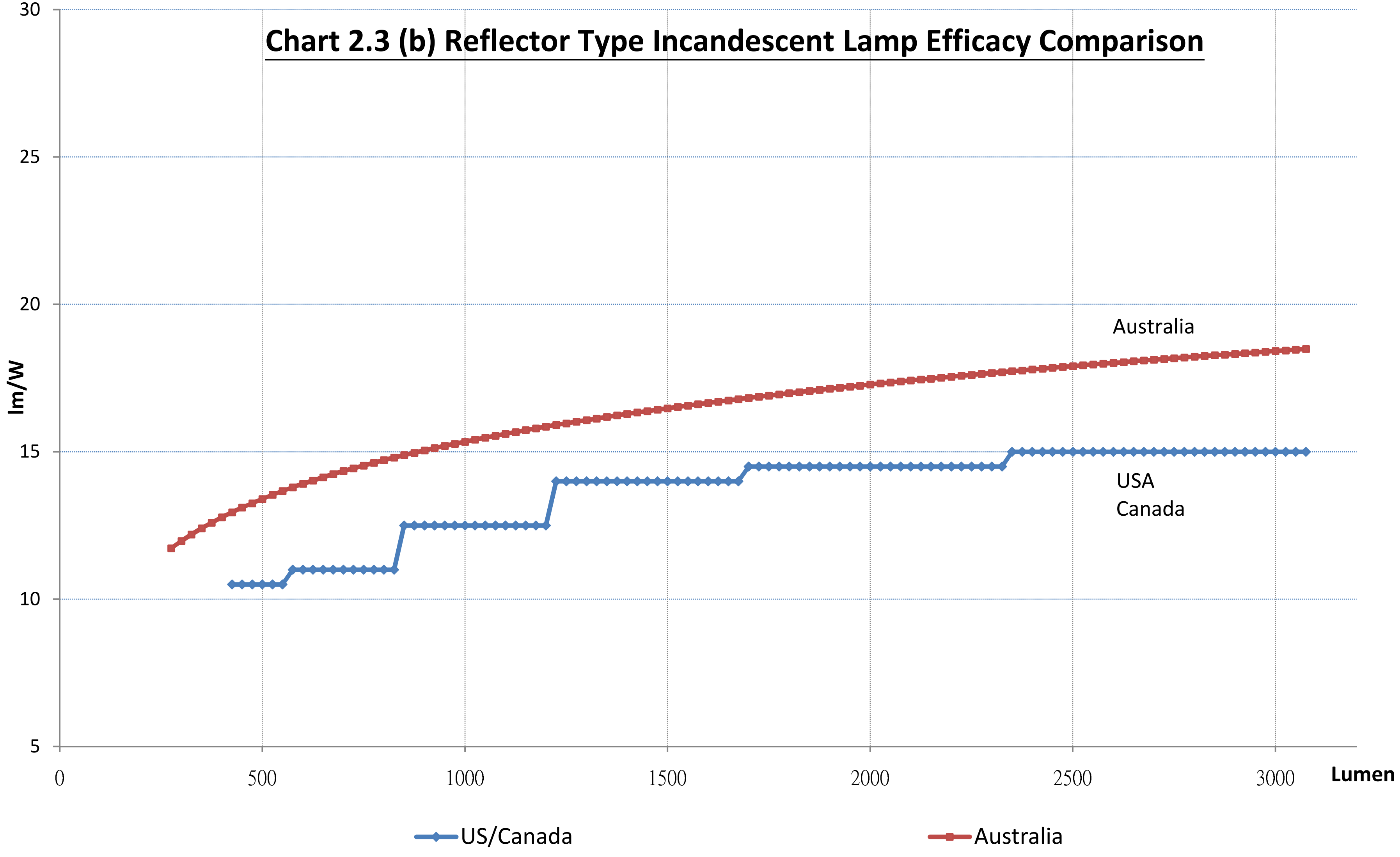


Chart 2.3 (b) Reflector Type Incandescent Lamp Efficacy Comparison
lm/W
30
25
20
15
10
5
0
500
1000
1500
2000
2500
3000
Lumen
Australia
USA
Canada
US/Canada
Australia

The efficiency requirement of different MEPS standard for non-reflector type incandescent lamps and reflector type incandescent lamps of the major countries are provided in Chart 2.3(a) and Chart 2.3(b) respectively. Generally speaking, the MEPS standard required in different countries/economics are quite similar.

The main purpose of phasing out incandescent lamps in these countries is to improve the overall energy utilization efficiency for lighting and to promote compact fluorescent lamps (CFLs) and other alternatives so as to replace the incandescent lamps. Therefore, most of these countries have also set regulatory requirement on the CFLs. Most of the countries that are implementing the phasing out programmes for incandescent lamps also have the regulatory requirement developed or being developed for the CFLs to avoid replacement of incandescent lamps by poor quality CFLs in the market Australia has MEPS standard passed to regulate the energy efficiency and minimum functional performance requirement of CFLs. As for the USA and Canada, they also set the requirements for the functional performance of the CFLs. The EU would also set the functional standard to regulate the CFLs in associate with the implementation of regulatory MEPS scheme for incandescent lamps.

3 Study on Viable Technology and Potential Replacement Options

3.1 Introduction

This study also covers the review for the viable technology of replacing energy inefficient incandescent light bulbs with alternative energy efficient lamps. With the viable technologies identified, they are subject to further analysis to evaluate whether such technologies are available for replacment of incandescent lamps. Availability means the replacement technologies can readily be selected by consumers to directly replace the incandescent lamps without the need to make major modifications to the circuitry of the lamp or to the lighting fixtures, etc. Therefore, in this study six availability criteria including average lamp life, color rendering, color temperature, lamp base, luminous efficacy and wattage range are employed to judge whether these viable technologies are considered available as replacement for incandescent lamps.

3.2 Different Lamp Types

The illumination, an indispensable part of the domestic, commerical, industrial and public, provides light source for various activities. Conventional electric lamps produce visible light either through the process of incandescence, (line) emission from a gas discharge and/or fluorescence. Lighting sources (lamps) using these processes range from the tungsten-filament bulb that has been commercially available for more than a century to various types of fluorescent lamps, halogen lamps, high-intensity discharge (HID; sodium, metal halide and mercury vapour) lamps. They are widespreadly used worldwide because each type of lamp technology exhibits different illumination effects and hence has different competitive edge at specific application.

Lighting system consists of lamps, luminaires (the lamp housing that helps to distribute the light into the space) and the control gear (which controls switching, ignition and regulation system). Choosing of the best lighting system for each specific task requires consideration of a range of performance characteristics. Apart from the consideration of selecting a lighting system capable of delivering the desired quantity and quality of light to the illuminated space, the choice of technology is influenced by considerations of economy, durability and aesthetics. The notion of quality is complex as it entails considerations of light distribution, glare avoidance and light spectral characteristics. In practical considerations different lamp technologies can have a wide range of performance characteristics. In the following sections the general sense and specific characteristics of each lamp technology are introduced with information being referenced to the international lighting guides and guidelines .

This section describes the different types of lamps by three catalogues and highlights the salient features of different lighting technologies and their specific application and performance characteristics. The purpose is to enable the readers to appreciate that different lighting technologies have different characteristics and specific application niches, and it is these considerations that make simple direct replacement of one technology by another difficult.

The types of lamp can be divided into the following categories according to the light source:

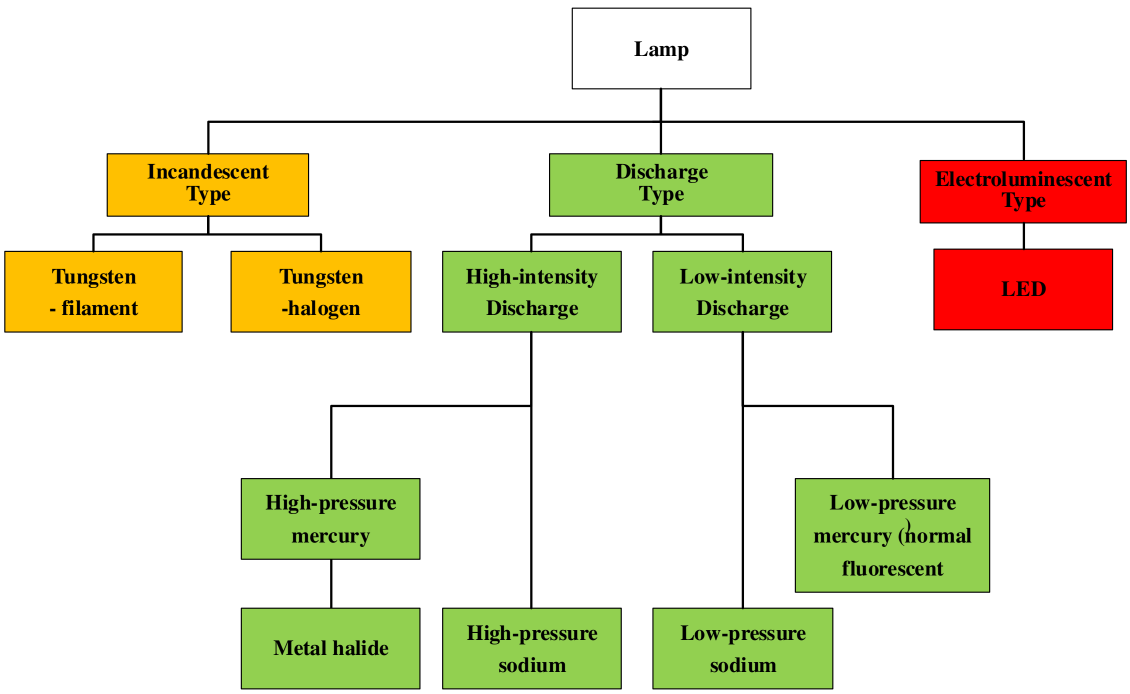
(a) Incandescent lamps
- i) Tungsten-filament including decorative lamps such as candle-shaped & fancy round lamps
- ii) Tungsten-halogen lamps including mains voltage non-reflector & reflector lamps, extra low voltage non-reflector & reflector lamps

(b) Gas discharge lamps
- i) Low pressure discharge
  - fluorescent lamps including linear fluorescent lamps T8 & T5 lamps, integrated CFLs and non-integrated CFLs
  - low pressure sodium (LPS) lamps
- ii) High pressure or HID
  - mercury vapour (MV) lamps
  - MH lamps
  - high pressure sodium (HPS) lamps

(c) Electroluminescent lamps
- g) LEDs

Figure 3.1 depicts the different categories of lighting technologies available on the market.

Figure 3.1 : Different Categories of Lighting Technologies Available on the Market



3.2.1 Incandescent lamps

a) Tungsten-filament lamp

Tungsten-filament lamps are the most common but are also the most energy inefficient light source. Tungsten-filament lamp produce lights by heating up a tiny coil of tungsten wire using electrical current.

i) General lighting service (GLS) lamps

Mains voltage incandescent lamps are commonly used in Hong Kong. They are available in typical pear-shaped or mushroom-shaped lamps with using either clear or frosted glass bulb and do not utilise halogen gas fill. With long history, various products such as colored and high wattage lamps are widely adopted in domestic, commerical, industrial and public premises illumination. High wattage lamps are classified for larger than 200 W and in typical pear-shaped. Colored lamps are used in aesthetics, creating atmosphere and attraction such as festival embellishment. One of special application is for chinese sacrificial altar in Hong Kong. High wattage lamps provide very strong sources of light, which are generally used for illumination of large rooms with high ceiling, task lighting, engineering workshops etc. The light produces in nearly all directions, i.e., close to ideal point source.

GLS lamps have very low efficacy and low life but low first costs. In Hong Kong, GLS lamps are commonly used for general, local, ambient and spot lighting. Light dimming is conveniently achieved by adjusting the voltage which has been possible for using simple power electronics components.

Figure 3.2 : Tungsten-filament lamp [15]

Larger wattage incandescent bulbs have a higher efficacy than smaller wattage bulbs. However, a larger wattage lamp or bulb may not be the most energy- or cost-effective option, depending on how much light is needed.

ii) Non-reflector tungsten filament lamps (such as Candle, Twisted Candle, Bent-tip Candle, Flame, Fancy Round, Globe lamps)

These mains voltage incandescent lamps are available in a range of varying shapes for decorative purposes e.g. in chandeliers used commonly throughout Hong Kong. They do not utilise a halogen gas fill. The decorative lamps have similar characteristics to GLS lamps and they are dimmable.

Figure 3.3 : Candle-shaped & Fancy round lamp [13, 16]

Another type, so called "Long-life" bulbs, with thicker filaments, is also a variation of these tungsten-filament lamps. Although these bulbs last longer than their counterparts, they are less energy efficient.

iii) Mains voltage reflector filament lamps

These mains voltage reflector lamps utilise an inert gas fill and include Parabolic Aluminized Reflector (PAR), Reflector (R), Elliptical Reflector (ER) and other lamp shapes.

Reflective coating inside the bulb directs light forward with various functions : Flood types (FL) spread light. Spot types (SP) concentrate the light. Reflector (R) bulbs put approximately double the amount of light intensity on the front central area as GLS of same wattage. Parabolic Aluminized Reflector (PAR) bulbs control light more precisely. They produce about four times the concentrated light intensity of GLS, and are used in recessed and track lighting. Weatherproof casings are available for outdoor spot and flood fixtures.

Reflector lamps are thus for concentrated light beams and not suitable where high lighting levels are necessary which are available in numerous spot and flood beam spreads. Beam angle control is considerable for applications.

Figure 3.4: Main voltage tungsten reflector lamp [16]

b) Tungsten halogen lamps

It is a type of incandescent lighting which achieves better energy efficiency (11 ~ 18 lm/W approximately) than tungsten-filament light bulbs (9 ~ 15 lm/W approximately).

Tungsten halogen lamps or quartz tungsten halogen lamps contain a halogen gas in the bulb, which reduces the filament evaporation rate and thus increases the lamp life. They also have an inner coating that reflects heat. Together, the filling and coating recycle heat to keep the filament hot with using less electricity. These lamps have a very high color rendition property. They also are considerably more expensive to buy than tungsten-filament lamps, but are less expensive to operate because of their higher efficacy.

The high operating temperature and need for special fixtures limits the use of tungsten halogens to commercial applications and for use in projector lamps and spotlights.

Some tungsten halogen lamps, especially for large wattage type, are designed to operate at the standard line voltage of 220 volts. However, some products are available in alternative line voltages of, for example, 110 volts, 240 volts or other line voltages.

i) Mains voltage halogen non-reflector lamps

These non-reflector lamps employ a halogen gas fill and are used in similar applications to GLS lamps. Efficacy is slightly higher than GLS and suitable for spotlighting or illuminating large areas. Basic characteristics are similar to GLS.

Figure 3.5 : Main voltage tungsten halogen lamp

ii) Mains voltage halogen reflector lamps

These mains voltage reflector lamps utilise a halogen gas fill which have similar characteristics with mains voltage halogen reflector lamps.

Figure 3.6 : Main voltage tungsten halogen reflector lamp

iii) ELV halogen non-reflector lamps

Low-voltage or extra-low voltage tungsten halogen lamps are commonly used for accent and display lighting applications where tight beam control is necessary. Typically rated for 12 volts operation, these lamps require a transformer (see section e) that converts incoming AC line voltage down to 12 volts. Accurate voltage transformation is required to maintain rated lamp life. The low-voltage operation enables lamp manufacturers to design more compact filaments, which enables the precise control of the light beam. Low-power low-voltage halogen lamp with short length tungsten filament are used extensively for decorative or exhibition lighting due to their excellent color rendering, compact size and robust. These lamps have specially-coated reflector that can reflect visible light but this reflector transmit 85% of heat producing by IR rays. Therefore they enjoy higher efficiency and longer lifespan than incandescent lamp.

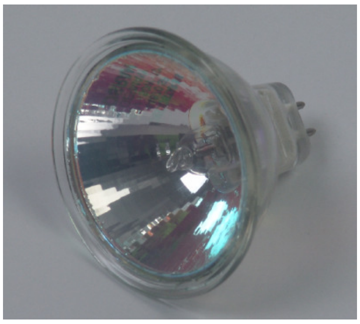
Extra low voltage 'capsule' lamps utilise a halogen gas fill for decorative application and spotlighting with the aim of the reflector of luminaries. The efficiency is slightly higher than mains voltage halogen non-reflector lamps due to low voltage effect. Aparting from low voltage operation, basic characteristics are simliar to mains voltage halogen non-reflector lamps.

Figure 3.7 : ELV halogen non-reflector lamp

iv) ELV halogen reflector lamps

These extra low voltage reflector lamps utilise a halogen gas fill and include 'dichroic' lamps. More precise beam angle control is considerable for applications. Aparting from low voltage operation, basic characteristics are simliar to mains voltage reflector lamps including halogen.

Figure 3.8 : ELV halogen reflector lamp [11]



v) Halogen Transformer (ELV Transformer)

Halogen transformers are typically used to provide an extra low voltage power supply to one or more capsule or reflector type halogen lamps.

Halogen transformers can be either magnetic or electronic. Magnetic transformers consist of a ferrous metal core wrapped with primary and secondary electrical windings. Electric current in the primary (mains) winding induces a magnetic flux in the core, which in turn induces a voltage in the secondary winding. The ratio of voltage reduction from the primary to secondary terminals is approximately proportional to the ratio of the number of coils in the primary and secondary windings. But the weight and size of a magnetic transformer are high lead to difficulty of wiring and installation. Moreover control of lamp power with a phase control dimmer is not possible.

Figure 3.9 : Magnetic ELV transformer for halogen lamps [24]

An electronic transformer (or more correctly 'electronic step-down converter') typically contains an electronic inverter which converts mains frequency AC (50 or 60 Hz) into high frequency AC (between 10 kHz and 100 kHz), which is then passed through a small magnetic transformer to reduce the output voltage to 12V AC at 10- 100 kHz. DC units are also available which rectify the high frequency output to DC, in order to reduce radio frequency interference and cable self-inductance over long circuits. Electronic transformers are smaller and lighter than magnetic transformers, and often include output voltage regulation with sophisticated transformer and lamp protection circuitry, soft starting, etc.

Figure 3.10 : Electronic ELV transformer for halogen lamps [24]

Halogen transformers are generally supplied with screw terminals, flying leads or in some cases a line mains plug. They are typically installed in a ceiling or wall cavity, in close proximity to the lamp in order to limit the required length of high current wiring. Magnetic transformers are typically compatible with common 'leading edge' dimmers, which remove the leading edge from the AC waveform, thereby reducing the average voltage. Electronic halogen transformers can be compatible with both leading edge and trailing edge dimmers, with only one dimmer type, or with none. More sophisticated electronic transformers incorporate inbuilt dimming circuits which are controlled by a dedicated dimming switch, rather than a conventional dimmer located electrically upstream from the transformer.

3.2.2 Gas discharge lamps

a) Low Pressure Discharge (Low Intensity Discharge Lamp)

i) Fluorescent Lamp

A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to shine, producing visible light.

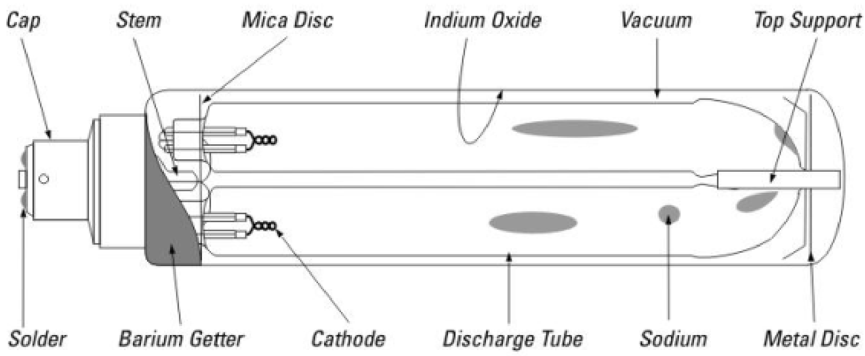
Unlike incandescent lamps, fluorescent lamps always require a ballast to regulate the flow of power through the lamp. However, a fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp; lower energy costs offsets the higher initial cost of the lamp. While larger fluorescent lamps have been mostly used in large commercial or institutional buildings, the compact fluorescent lamp (CFL) is now being used as an energy-saving alternative to incandescent lamps in homes. Compared with incandescent lamps, fluorescent lamps use less power for the same amount of light, generally last longer, but are bulkier, more complex, and more expensive than a comparable incandescent lamp.

Figure 3.11 : Various forms of fluorescent lamp [15]

ii) Low Pressure Sodium (LPS) Lamp

Since its commercial introduction in 1932, the Low Pressure Sodium lamp has consistently maintained its enviable position as the most efficient light source available. Current LPS lamps are known as the SOX type, and the entire global supply of approximately four million pieces per year is made. The construction of a typical SOX lamp is illustrated in the figure below.

Figure 3.12 : Construction of a typical SOX lamp [20]



SOX lamps are generally employed in street lighting applications, primarily because they are the most efficient light sources available. This means that they deliver more lumens of visible light for each watt of power than any other types of lamps. SOX installations therefore have the lowest energy consumption costs which is of crucial importance when thousands of miles of roads must be illuminated at lowest electricity cost. The principal reason for the high efficacy is because the color of the light is close to the maximum sensitivity of the human eye in normal viewing conditions.

b) High Pressure Lamp (High Intensity Discharge Lamp)

A High-intensity discharge (HID) lamp is a type of electrical lamp which produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube. This tube is filled with both gas and metal salts. The gas facilitates the arc's initial strike. Once the arc is started, it heats and evaporates the metal salts forming a plasma, which greatly increases the intensity of light produced by the arc and reduces its power consumption. High-intensity discharge lamps are a type of arc lamp.

Compared with fluorescent and incandescent lamps, HID lamps have higher luminous efficacy since a greater proportion of their radiation is in visible light as opposed to heat. Their overall luminous efficacy is also much higher: they give a greater amount of light output per watt of electricity input.

i) Mercury-vapor lamp

A mercury-vapor lamp is a gas discharge lamp which uses mercury in an excited state to produce light. The arc discharge is generally confined to a small fused quartz arc tube mounted within a larger borosilicate glass bulb. The outer bulb may be clear or coated with a phosphor; in either case, the outer bulb provides thermal insulation, protection from ultraviolet radiation, and a convenient mounting for the fused quartz arc tube.

Mercury vapor lamps (and their relatives) are often used because they are relatively efficient. Phosphor coated bulbs offer better color rendition than either high- or low-pressure sodium vapor lamps. They also offer a very long lifetime, as well as intense lighting for several applications.

Figure 3.13 : Mercury vapor lamps [15]

ii) Metal halide lamp

Metal halide lamps, also a member of the high-intensity discharge (HID) family of lamps, produce high light output for their size, making them a compact, powerful, and efficient light source. Originally created in the late 1960's for industrial use, metal halide lamps are now available in numerous sizes and configurations for commercial and residential applications. Like most HID lamps, metal halide lamps operate under high pressure and temperature, and require special fixtures to operate safely. They are also considered a "point" light source, so reflective luminaires are often required to concentrate the light for purposes of the lighting application.

Figure 3.14 : Metal halide lamp [15]

iii) High pressure sodium (HPS) lamp

High pressure sodium (HPS) lamps are smaller and contain additional elements such as mercury, and produce a dark pink glow when first struck, and a pinkish orange light when warmed. Some bulbs also briefly produce a pure to bluish white light in between. This is probably from the mercury glowing before the sodium is completely warmed. The sodium D-line is the main source of light from the HPS lamp, and it is extremely pressure broadened by the high sodium pressures in the lamp; due to this broadening and the emissions from mercury, colors of objects under these lamps can be distinguished. This leads them to be used in areas where good color rendering is important, or desired. Thus, its new model name SON is the variant for "Sun" (a name used primarily in Europe and the UK). HPS Lamps are favored by indoor-growers for general growing because of the wide color-temperature spectrum produced and the relatively efficient cost of running the lights.

High pressure sodium lamps are quite efficient—about 100 lm/W—when measured for photopic lighting conditions. They have been widely used for outdoor lighting such as streetlights and security lighting.

Figure 3.15 : High pressure sodium (HPS) lamp [15]

3.2.3 Electroluminescent lamp

a) Light-emitting-diode (LED)

A light-emitting-diode (LED) is a semiconductor diode that emits light when an electric current is applied in the forward direction of the device, as in the simple LED circuit. The effect is a form of electroluminescence where incoherent and narrow-spectrum light is emitted from the p-n junction in a solid state material.

LEDs are widely used as indicator lights on electronic devices and increasingly in higher power applications such as flashlights and area lighting. An LED is usually a small area (less than 1 mm^2) light source, often with optics added directly on top of the chip to shape its radiation pattern and assist in reflection. The color of the emitted light depends on the composition and condition of the semiconducting material used, and can be infrared, visible, or ultraviolet. Besides lighting, interesting applications include using UV-LEDs for sterilization of water and disinfection of devices, and as a grow light to enhance photosynthesis in plants.

Figure 3.16 : Light-emitting-diode (LED) [13]

White light emitting diodes (WLED)

White light LEDs were first developed in the mid 1990s. Since then their development has been very rapid. Some of the white LEDs presently available in the market have a luminous efficacy of the order of 24 lumens per watt, which is greater than the luminous efficacy of halogen incandescent sources. Being a low voltage and small package light source, LED is a good candidate for outdoor landscape lighting applications. The life of white light LEDs are being projected to 25,000 hours with 70% lumen maintenance. Being rugged, durable, and having a long lifetime makes the LED even more attractive for this target application. White light from LEDs can be created in several ways. The two most common techniques presently employed are the excitation of a down conversion phosphor with the blue light emitted by a semi conductor, and the mixing of multiple colored LEDs, such as red, green, and blue (RGB), in appropriate proportions. Each of these techniques has advantages and disadvantages. The phosphor approach provides a single integrated LED package, whereas the RGB approach requires some form of external mixing element to get good quality white light. However, the RGB LEDs provides a more efficacious lighting system and higher lumens per watt as compared to the phosphor method, because the down conversion method involves losses. Furthermore, they have significantly different spectral power distributions (SPD) that will result in making the lighted space appear different.

3.3 Viable Technology

A detail review to bring up to date information on the technology movement toward developing energy efficient lamp technology is described in this section. It is firstly defined the criteria of judging the viability of lighting technology and then studied the viable technology for incandescent lamp and low-efficacy metal halides, metal halides (MH), linear fluorescent lamps (LFL) and compact fluorescent lamps (CFL).

3.3.1 Criteria of Viability

This section describes the criteria for judging whether a specific lighting technology is viable for replacement of inefficient incandescent lamps or other lamps. Such viability criteria would include higher efficacy, lumen maintenance / depreciation, start-up or re-strike time, lighting control system and light quality (including burnouts / lifetime, and colour rendering) for the incandescent lamp replacement.

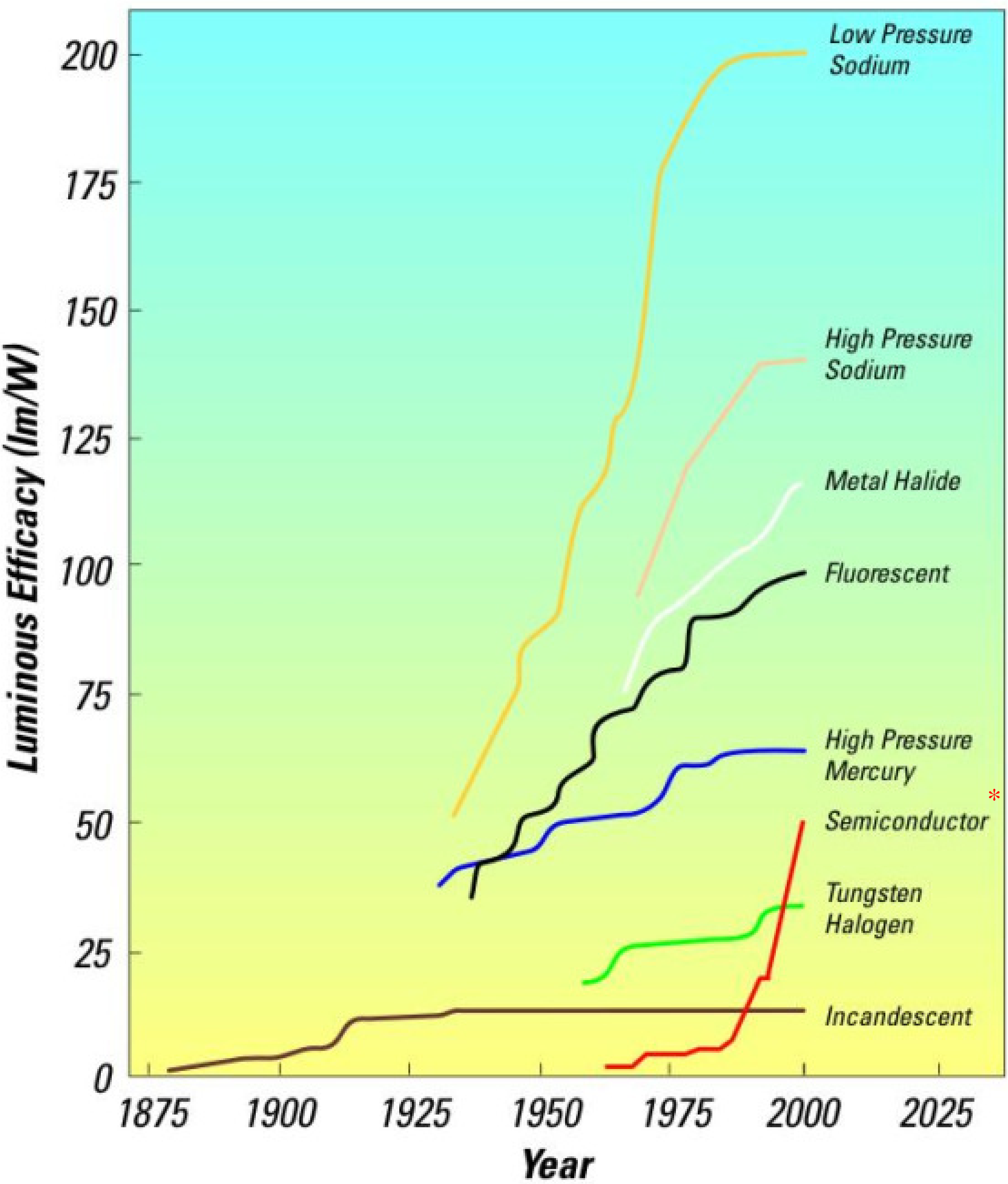
a) Efficacy

The efficacy of a lamp is defined as the ratio of the light output to the input power and is measured in units of lumens per watt (lm/W). The higher the efficacy the lower the energy required to deliver a given amount of light. The efficacy of a lighting system is not determined just by the efficacy of the lamp, however, as many lighting systems also require energy-consuming control gear (most commonly ballasts). Thus a better determination of the energy performance of a lighting system is given by a comparison of system efficacy values, which takes this into account.

Table 3.1 : Typical performance of different lighting technologies.

Type	**Efficacy**
GLS	9 - 15 lm/Watt
Standard Halogen Lamp	11 - 18 lm/Watt
Advanced Halogen Lamp (e.g. Infrared Halogen Lamp)	21 - 40 lm/Watt
CFL (Ballast Integrated or Modular)	30 - 65 lm/Watt
Metal Halide Lamp	45 - 110 lm/Watt
Fluorescent Lamp/High-efficiency Fluorescent Lamp (e.g. T8, T5, etc)	55 - 100 lm/Watt
LED/WLED	10 - 55 lm/Watt Remark : Efficacy depends upon the technology and manufacturer. Some manufacturers claim a much higher value [22]

Figure 3.17 : Effects of Technological Progressions on the Efficacy of Light Sources [20]



* Remark : The most common type of semiconductor light source is LED

b) Lumen Maintenance/Depreciation

A true comparison between lighting systems is further complicated by the fact that the light output and hence efficacy of most lamp types diminishes over time through a phenomenon called "lumen depreciation". Depending on the lamp type, light output will diminish by up to 40% over the operational lifespan. The lumen depreciation characteristics of the lighting system need to be considered when selecting an appropriate lighting system to deliver the required lighting levels; as a result, lighting designers usually install systems based on their "maintained lumen" levels, where the maintained lumen rating is the expected lumen output at some percentage of the lamp life (usually 70 or 80%). This means that the initial lighting level will be higher than required. For most lamp types the power level drawn tends to remain constant as the light output depreciates, and as a result the efficacy also declines over the course of the operating life. The inverse relationship is true for low pressure sodium lamps, which tend to have constant light output but draw more power over the course of their operating life, although this also results in efficacy depreciation. Tungsten halogen lamps are unique in that their efficacy only varies by a few percent over the life of the lamp. For the remaining types of lamp the degree of lumen depreciation depends on the technology considered. Lumen depreciation is particularly rapid for HID and fluorescent lamp types during the first 100 operating hours, thus by industry consensus manufacturer lamp light output and efficacy ratings are established after that time. Nonetheless the extent of ongoing depreciation can be significant and is an important factor to consider when comparing systems.

Some electric lamp's efficiency varies with operating temperatures such as T5 fluorescent lamp will not operate efficiently if the temperature is too low and this limits their applications in certain outdoor environments. Despite this they can be applied in environments with very low temperatures with the proper lamp, ballast and luminaire. The efficacy of many electric lamps is insensitive to temperature, but this is not the case for fluorescent lamps or solid-state/semiconductor lighting devices, i.e. LED.

c) Start-up or Re-strike Time

There are applications where instant turning on of the lamp is required. For some products such as Ceramic metal halide lamp, an inherent start-up time around minutes is required to light up the lamp. Although modern electronically-ballasted CFLs are faster to ignite than their earlier magnetically-ballasted cousins, some take up to one minute to reach 90% of brightness from when first energized and usually at least ten seconds before reaching 50% of full brightness.

d) Lighting Control System

Lighting controls are critical for minimizing lighting energy use and maximizing space functionality and user satisfaction. Control techniques ranges from simple to extremely sophisticated.

Two-wire control system

Most of these controls in the market have been designed around incandescent lamps (which are purely resistive loads) and will not work properly with most energy efficient lamps. This appears to be the case for ‘two-wire’ controls, where no neutral is connected to the control device and thus the control device relies on a bleed current through the connected lamp to power its electronics. Many standard CFLs do not function well with this current, and control circuitry can also interact adversely with CFL electronics, leading to unpredictable effects. The major two-wire controls in Hong Kong are as follows:

i) Manual Switches

Manual switches are the simplest form of user-accessible lighting control. They are especially valuable in occasional occupation and daylight building spaces because they allow people to turn off electric lights when out or daylight is adequate. Manual switches could be installed in spaces with occupancy sensors to increase the energy savings by allowing people to turn off the lights when they are not needed.

ii) Occupancy Sensors

Occupancy sensors employ motion detectors to shut lights off in unoccupied spaces. The primary detection technology can be either passive infrared (PIR) or ultrasonic. Some sensors employ both passive infrared and either ultrasonic or microphonic detection. Mounting configurations include simple wall box sensors appropriate for small spaces such as private offices, and ceiling- or wall-mounted sensors that provide detection of areas up to 180 m^2. Occupancy sensors are most effective in spaces that are intermittently occupied, or where the lights are likely to be left on when unoccupied. The best applications include classrooms, offices, restrooms, public and storage areas. Use occupancy sensors in combination with manual overrides whenever possible to maximize energy savings, space flexibility, and occupant satisfaction. Including manual off override to the control scheme allows the user to turn the lights off for presentations or other situations requiring the lights to be off.

iii) Timer Controls

Timer controls save energy by reducing lighting time of use through preprogrammed scheduling. Timer control equipment ranges from simple devices designed to control a single electrical load to sophisticated systems that control several lighting zones.

Timer controls make sense in applications where the occupancy hours are predictable, and where occupancy sensor automatic control is either impractical or undesirable.

iv) Manual Dimmers

Next to standard wall switches, manual dimmers are the simplest of lighting control devices. Manual dimmers serve two important functions. First, dimming lights reduce lighting demand and energy usage. With incandescent and halogen sources, there is the additional benefit of extended lamp life. However, more importantly, dimmers allow people to tune the lights to optimum levels for visual performance and comfort.

The basic principle of dimmers is to vary the intensity of the light output by decreasing or increasing the RMS voltage and hence the mean power to the lamp. Small domestic dimmers are generally directly controlled, although remote control systems (such as X10) are available. Modern professional dimmers are generally controlled by a digital control system like DMX or Ethernet.

Modern dimmers are built from silicon-controlled rectifiers (SCR) instead of potentiometers or variable resistors because they have higher efficiency (efficiency close to 1.0) but can damage some common lamps such as CFL[3].

v) Photosensor/daylight sensor controls

Photosensor control systems are used to control electric illumination levels in daylight spaces. A photosensor detects the daylight illumination level and sends a signal to a logic controller to switch off or dim the electric lights in response. In open-loop systems, the sensor is placed so that it “sees” a representative daylight level, such as looking up into a skylight or out a window. In a closed-loop system, the sensor is placed so that it “sees” both the daylight and electric illumination level combined.

vi) Energy Management Systems (EMS)

Typically an EMS controls lighting via a time clock. However, many building operators take advantage of the built-in EMS functions to monitor lighting usage on a space-by-space basis. EMS control of lighting systems may also allow building operators to dim or turn off lights in order to shed nonessential lighting loads during peak demand periods.

e) Light Quality

The performance and features of a light source needs to match the lighting task being performed. In order to select the suitable light source for the job, users would consider important performance variables such as lamp burnout rate, color rending, etc.

<u>i) Lamp Burnouts / Lifetime</u>

When a lamp expires, it becomes a “burnout”. Lighting designers usually assume that the burnout will be replaced immediately. However, if it is known that the lamps are too easy to burnout, then an illumination quality loss and replacement effort must be reckoned by users.

<u>ii) Color Rendering</u>

[3] A manufacturer has produced smooth dimming and step dimming with a dimmer switch and on/off switch, respectively.

Color rendering properties are measured in terms of the Color Rendering Index (CRI). The CRI is a measure of the degree to which a light source renders colors that are close to true color. For practical purposes it is a number from 0 to 100; the higher the number, the closer to true color. The efficiencies of each type of light source can vary dramatically, so the choice of light source can have a dramatic impact on lighting energy costs. The CRI of incandescent lamp including halogen lamp have an excellent CRI approaching 100.

3.3.2 Viable Technology for Incandescent

Illumination energy costs have become a significant concern and are expected to continue to increase in the foreseeable future. Businesses, institutions and consumers will be searching for more efficient products and solutions to replace inefficient lamps. Over the years development in lamp technology has led to improvements in efficacy of lamps. However, the low efficacy lamps, such as incandescent bulbs, still constitute a major share of the lighting load. High efficacy lamp types such as gas discharge lamps suitable for different types of applications offer appreciable scope for energy conservation but also with considerable limitations.

Suitability of Replacement Lamps for Incandescent

Incandescent lamps are widely used in different areas with many lamp types as stated in section 3.2.1. An international survey *"Global Efforts to Phase-Out Incandescent Lamps"* [11] conducted by International Energy Agency (IEA) addressed that many policies and regulations were developed to aim at phasing out inefficient incandescent lighting. The intention of those polices and regulations already adopted or under consideration is to encourage energy savings through the usage of higher efficiency lamps and most notably the use of compact fluorescent lamps (CFLs) in place of tungsten-filament lamps. The countries which are currently actively developing policy measures to phase-out incandescent lamps account for roughly half the global GLS market and consume about 6.5 billion GLS per year out of a global market volume of approximately 12.5 billion lamps. Other countries may also be poised to introduce similar initiatives in the near future.

However, International Energy Agency also concluded that CFLs are not the only alternative to conventional general service incandescent lamps and there are other lamp technologies which could be used in place of GLS lamps that have higher (or slightly higher) energy efficiency but are not as efficient as CFLs. They include: advanced halogen lamps, which can have efficiencies that are between a few percent better than GLS to up to twice as high as GLS depending on the technology used; and light emitting diodes (LEDs), which are just beginning to appear on the market.

LED technology is making great advances; however, it is still unclear how viable it will eventually be as a replacement for general service incandescent lamps. There is uncertainty about the future rate of product development and the eventual market acceptance of LED costs, light level and distribution characteristics, heat dissipation and chromatic properties. Under such circumstances the magnitude of energy savings resulting from the regulations would depend on the relative preference expressed in the market place for the less-efficient compliant lamp options and for CFLs. In the lower extreme energy savings could be as little as 10 to 20% of GLS lamp energy consumption as compared to roughly 75% with the full adoption of CFLs. The following section illuminates those international commonly accepted replacement options in relation to the phase-out of incandescent lamps and provides information on their current status.

a) Compact Fluorescent Lamp (CFLs)

The suitability of CFLs as replacements for incandescent lamps has increased significantly in the last decade due to on-going improvements in the lamp technology and their production. CFLs are now available at much lower prices than hitherto, they come in a much larger range of dimensions and thus models can be found which will fit into almost all light fixtures using a screw-based socket, and their light quality has improved substantially. Because they require only a quarter to a fifth of the energy of conventional GLS lamps, CFLs are far more economical to operate and hence are more cost-effective for the end-user. They also last between five and fifteen times as long as a standard GLS lamp (5,000 to 15,000 hours for CFLs compared with 750-1,500 hours for GLS).

The limitations of CFLs compared with GLS lamps are that good CFLs give out light with a colour-rendering index (CRI) of larger than 80 as compared with that from an incandescent or halogen lamp of 100. This means that they are not quite as good at producing a faithful rendering of colour as are incandescent lamps. For most applications a CRI of > 80 is perfectly adequate for end-users but there may be some cases where end-users would prefer a higher CRI. While an incandescent lamp produces light as soon as they are switched on there is a very short delay for CFLs and the lamps take slightly longer to produce their full light output.

Furthermore, CFLs are available in much smaller sizes than was previously the case there is a limit to how small they can be made as far as these may be better suited to certain kinds of lamp fixtures.

In the view of toxic waste, CFLs contain trace levels of mercury. The levels included in modern lamps are much less than was previously the case but some economies are introducing requirements for their safe disposal at end of life.

CFLs are not as well-suited to provide well directed beams of light as are certain types of incandescent lamps (most notably halogen reflector lamps) and hence are not adapted to provide some types of reflector lamp applications.

Furthermore, many CFLs will not operate reliably on circuits that incorporate a dimmer switch or other control device such as a motion/occupancy detector, photosensor/daylight sensor or electronic timer. For an incandescent dimmer was previously installed, most of these controls in the residential market have been designed around purely resistive loads and will not work properly with CFLs (see section 3.3.1d). While there are various controls that will work with CFLs or other fluorescent products, they are not fully available in the residential market readily. While there are various controls that will work with CFLs or other energy efficient products, they are required to modify or replace the control system.

Figure 3.18 : Different CFLs [15]

Major Pros & Cons of CFL

Pros	Cons
1. More cost-effective. 2. CFLs can last 6 to 10 times longer. 3. Newer generation CFLs come in cool light, soft light and day light versions, making it easier for users to choose different types of lights for different rooms in the house.	1. High first price. 2. Contain trace amount of mercury. 3. CRI is not as good as incandescent lamps. 4. Certain manufactures make poor CFLs. 5. Quality and environmental standards are developing. 6. Size and shape may not fit all the lanterns/fixtures 7. No enough variety of shapes and sizes to match every family's personal preference. 8. Not suitable for existing control circuit.

b) Advanced Halogen Replacement Lamps (AHLs)

i) Halogen lamps with xenon gas filling

With xenon gas filling, the halogen lamp will use about 25% less energy for the same light output compared to the best incandescent, even at mains voltage. Some manufacturers improve the halogen capsule to place in glass bulbs shaped like incandescent lamps with traditional socket, which makes it compatible with all luminaires using incandescent lamps.

These types of halogen lamps are produced in a wide variety of shapes and functions, for example, non-reflector and reflector lamp. However, the basic principle and characteristics remain unchanged.

Figure 3.19 : Halogen lamps with xenon gas filling [12]

ii) Halogen Infrared Reflecting Lamps (HIRL)

The halogen infrared reflecting lamp is a major advancement in incandescent lighting technology. By encapsulating the incandescing filament in a specially-formed quartz capsule onto which a multi-layer coating has been deposited, lamp engineers have created the HIRL which is much more efficient than a tungsten-filament or tungsten halogen lamp. The multi-layer coating allows visible light to pass but wasted heat (infrared radiation) is reflected back onto the filament. This reflected heat warms the filament, thus reducing the need to supply electrical power and improving efficiency. The improvement in efficacy with this technology is impressive.

Figure 3.20 : HIRL with integrated transformer [12]

Present style HIRL lamps can have higher energy efficiency than conventional GLS lamps but cannot attain the levels of CFLs with today's technology. The most efficient halogen lamps, which are just in the process of being commercialised on Organisation for Economic Co-operation and Development markets, have an efficiency that is roughly twice as high as for a comparable GLS lamp. They have the same high colour rendering (i.e. a CRI of 100) and last two to three times as long as a GLS (2,000 to 3,000 hours compared with 750-1,500 hours for GLS lamps). With today's lamp technology it is possible to produce halogen lamps that could substitute for almost all conventional GLS applications and that would give energy-savings up to 50% depending on the explicit halogen technology used. It is expected that the most efficient varieties will be significantly more expensive than GLS and even CFLs when first entered on the market and that their price will decline as and when their market volumes increase. It is not easy to estimate whether halogen or CFL lamps would be the cheapest in a market where no conventional GLS lamps were permitted to be sold, but it seems likely that CFLs would be cheaper than the most efficient halogen lamps at least in the short term. There is no retail available HIRL products but only on project procurement basis in Hong Kong.

Low-voltage effect

The coil wire of a low-voltage lamp (e.g. 12 V) is much thicker (e.g. five times) than that of a high-voltage lamp with the same output. In addition, the length of the coil wire of a low-voltage lamp is only about, e.g. one-fifth of the length of a comparable high-voltage coil. This results in the significantly higher thermal resistance of the low volt coils. This in turn leads to higher light efficiency and a considerably longer product life than is true for high-voltage lamps. Low voltage lamps require a transformer either in the luminaire or integrated into the lamp.

Major Pros & Cons of HIRL

Pros	Cons
1. Higher efficiency. 2. Similar size and shape could be achieved for direct replacement. 3. High CRI. 4. Longer lifetime. 5. Suitable for existing incandescent control system.	1. Very high first cost. 2. Full product range not available. 3. Limited manufacturers.

c) Light emitting diodes (LEDs)

One technology which shows considerable promise is light emitting diodes (LEDs). This may be a pessimistic projection as LEDs of up to 55 lm/W are starting to reach the marketplace in the USA [22]. LEDs are solid-state semiconductor devices that convert electrical energy directly into light. LED 'cold' generation of light can lead to high efficacy because most of the energy radiates in the visible spectrum. Currently, LEDs do produce significant quantities of heat within the material itself which means that there is a significant need for good heat sinking.

New LED materials and improved production processes have produced bright LEDs in colours throughout the visible spectrum, including white light, with efficacies greater than incandescent lamps. However, at present they are both less efficient and more expensive than CFLs. On the other hand, considerable technical advances and price reductions are occurring and U.S. Department of Energy's long-term research and development goal calls for white LEDs producing 160 lm/W in cost-effective, market-ready systems by 2025. LEDs also have very long lifetimes, up to 100,000 hours, so can also offer environmental advantages in terms of resource use. The newest development is in the use of gallium nitride (a man-made semiconductor). An LED using this material is exceptionally energy efficient and long lasting and the technology offers obvious potential benefits to domestic, commercial and public users, thus all major manufacturers are involved in development in this area. LEDs are a very promising lighting technology, not only for their future energy saving potential, but also because of their user-friendliness (eg no flickering, no high voltage, reduced electromagnetic interference, robust, suitable for every design, long lived, etc.

Currently, the most efficacious white LEDs can perform similarly to fluorescent lamps. There are several concerns which needs to be addressed:

(a) LED light output and useful life are strongly affected by temperature,

(b) Not easy to provide adequate amounts of light,

(c) Not easy to provide light distribution in a manner which satisfies consumer needs,

(d) Color quality is evolving, and

(e) Good quality LED is expensive.

Colored LEDs are already being used in Hong Kong's traffic lights to replace tungsten filament bulbs. LEDs are also a leading light source for exit signs and appear in display, decorative, and transportation applications, with plenty of opportunity for expansion. Small, lightweight, durable, and with a long life, LEDs have the long-term potential to be the source of choice in many applications, from automotive lights to task lights. The initial products have been concealed lighting (eg under cupboards) and task lighting (eg desk lamps). Small display spotlights are available now, although the quality of some of these lamps is still questionable at present. Warm white LEDs are starting to appear on the market to add to the original cool, blue-white lamps. Some manufactuers have lanuched few low wattage range LED products in retail level in these years.

Figure 3.21 : Light emitting diodes (LEDs) lamp

Major Pros & Cons of LED

Pros	Cons
1. Higher efficiency. 2. Low power consumption and low heat generation. 3. Extremely long life. 4. Negligible early failures. 5. High color efficiency (because they are monochromatic) 6. Very small. 7. Resistant to damage from shock and vibration. 8. No infra-red or ultra-violet energy is emitted.	1. Very high first cost. 2. Full product range not available. 3. Not available for high wattage. 4. Strict working environment requirement (e.g. temperature). 5. Quality problem.

d) Metal Halides (MHs)

Apart from the above-mentioned replacement options, Metal halide lamps are one of the fastest growing light sources in the world today.

Metal Halide lamps have gone through a revolution of change and improvement again in the Mid'60. New technology, particularly pulse start technology, now allows users to select among a broad variety of lamp types to suit a wide range of applications. Many manufacturers have developed numerous unique lamps to satisfy various applications. Advancements in lamp and ballast designs along with the inherent qualities of metal halide lighting account for its phenomenal growth. New lamps types have made it possible to use metal halide in almost any setting, including industrial, commercial, retail and residential applications.

Metal halide is a highly efficient, compact source of white light, available in a variety of different color temperatures to accommodate users' needs. In contrast, high pressure sodium and mercury lamps are very limited in the color and quality of light they produce. The colors they generate are often unpleasing or inappropriate for many applications. This helps explain why the use of metal halide lamps continues to increase dramatically each year around the world.

Metal halide lamps have exceptionally long rated lives of up to 30,000 hours and this light source can be manufactured to produce almost any color of light desired (2,700K – 20,000K) and also offers an excellent color rendering index (CRI) of 65-90+. Specialty lamps of specific colors can also be produced.

Major Pros & Cons of MH

Pros	Cons
1. Higher efficiency. 2. High CRI. 3. Long lifetime. 4. Close to ideal point source.	1. High first cost. 2. Full product range not available. 3. Limited manufacturers. 4. Circuit modification may be needed. 5. Generally cannot be burnt in any position. 6. Lumen depreciation and color stability problem.

3.4 Available Replacement Options

Higher efficiency alternatives to incandescent lamps have been available since the commercialization of the compact fluorescent lamp (CFL) to Hong Kong in the 80s ~ 90s. CFLs use between a quarter and fifth of the energy of equivalent incandescent lamps and so constitute a much more efficient alternative. They are also far more economic over the life cycle of the lamp, such that with typical tariffs and lamp costs a consumer would save over two thirds of the total cost of the lighting service by using CFLs in place of incandescent lamps.

Despite technological and commercial advances CFLs are still struggling to overtake incandescent lamps in many core markets; not least because of the existence of some important market and technical barriers. Barriers include: size, weaker color depiction, uncontrollability (for example, dimming), consumer always consider initial cost but not long term operating cost, cannot cope with special application and highly variable product quality. But CFLs are no longer the sole alternative to traditional incandescent lamps: new intermediate or high efficiency solutions are reaching the market based on infra-red halogen or solid state lighting technology etc, each of which present advantages and limitations compared to CFLs. Generally, people consider the feasibility of replacing existing lighting with more efficient lighting that depends on the size, application (illumination requirement) and the cost of replacement versus the savings.

This chapter describes the criteria for availability including higher efficacy, light quality, similar shape or size, lumen depreciation, lifetime, wattage, cost, lamp cap, color rendering index, color temperature, etc.

3.4.1 Criteria of Availability

Apart from economical factors and general technical information, in this section uses several technical parameters to determine the light quality and performance of any lamp including the lamp's initial light output (in lumens), efficacy (in lm/W), life time (in hours), wattage (in W), cost (in HKD), lamp cap, etc. Two additional parameters are used to indicate light quality: correlated color temperature (CCT) and color rendering index (CRI). CCT (in degrees kelvin, K) is used to measure the perceived "whiteness" of a lamp, ranging from around 2,700K, to over 5,000K. CRI measures the degree of color shift objects undergo under the various lamp technologies compared to a reference incandescent light source of comparable color temperature. It is measured on a scale of 1 - 100, with 100 being equal to color rendering of the reference lamp. These issues are complex, and equally complex solutions are needed to address them. The technical issues are mixed and complicated in themselves. The following table summarizes the terms/factors which dramatically affect the decision of replacement.

Table 3.2: Terms of Criteria for Lamps

Term	**Description**
Average lamp life (hours)	The average lamp life in term of hours. For example, there are two kinds of energy-savings CFL: standard lamps live approx. 6,000 hours, long-life lamps live 10,000 to 15,000 hours. When frequent switching (more than 3 to 6-switches a day) the lamp life can shorten with standard lamps; when frequent switching (up to 100-swiches per day) the more expensive, long-life lamps should be used.
Color Rendering	The most widely cited metric of a source's rendering capability is Color Rendering Index (CRI), defined in the CIE publication 13.3-1995 "Method of Measuring and Specifying Color Rendering Properties of Light Sources" including specifically defined calculation procedures and surfaces.
Color temperature (Kelvin)	The light color appearance of a lamp can be defined in terms of its Color Temperature. There are three main color groups: warm whites < 3,300 K; neutral whites 3,300 K - 5,000 K and daylight whites > 5,000 K.
Lamp Base	Different screwable thread or bayonet-base lamp adaptors. For example, E27: screwable thread (Edison) with diameter 27 mm E14: screwable thread (Edison) with diameter 14 mm GU10: Bayonet-Base, distance of the pins: 10 mm GX53: Bayonet-Base, distance of the pins: 53 mm This is to check against whether the lamp is directly replacement or not.
Luminous efficacy	Luminous efficacy indicates the efficiency with which the electrical power consumed is converted into light.
Luminous flux (Lumen)	The luminous flux indicates all the radiated power emitted by a light source in all directions, evaluated at spectral eye sensitivity; usually provided in lamp catalog.
Wattage (Watts)	Electrical power consumption; indication on both packing and lamp catalog.

3.4.2 Summary of Replacement Availability

With respect to those criteria of availability mentioned in section 3.4.1 above, this section 3.4.2 explains and summarizes the various available replacement options for seven major inefficient incandescent lamps in Hong Kong market:

1. General Lighting Service (GLS)
2. Decorative lamps (such as candle-shaped & fancy round lamps)
3. Mains voltage halogen non-reflector lamps
4. Extra low voltage halogen non-reflector lamps
5. Extra low voltage halogen reflector lamps
6. Mains voltage reflector lamps including halogen
7. Pilot lamps, refrigerator and oven lamps

These six criteria including average lamp life, color rendering, color temperature, lamp base, luminous efficacy and wattage range are employed to judge the availability of replacement options among three common suppliers in Hong Kong with remarking certain constraints. Furthermore, indicative prices are also listed for reference. Some replacement options such as AHL are not available in retail market with expensive price but it can be expected that continuous price drop could accompany with increasing market demand built by consumer awareness.

Table 3.3: Available technologies listed against different types of incandescent lamps

Type of Incandescent Lamp	Wattage Range (W)	Available Replacement Technology	Limitation
GLS	Up to 100W	1. CFL 2. LED 3. AHL	1. LED is available for replacing low wattage incandescent lamps only 2. Lower CRI of LED may not match requirement for specific applications 3. Size and shape of LED may not suit all application requirements 4. Higher lamp cost
	100W to 200W	1. CFL	1. Size and shape of CFL may not suit all application requirements (e.g. stage lighting fixtures) 2. Higher lamp cost
Other Tungsten Filament Lamps	All wattage	1. CFL 2. AHL	1. Lower CRI of CFL may not match requirement for specific applications 2. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely

Type of Incandescent Lamp	Wattage Range (W)	Available Replacement Technology	Limitation
			available in the retail market 3. Higher lamp cost
Main Voltage Halogen Non-reflector Lamps	Up to 150W	1. CFL 2. AHL	1. Size and shape of CFL may not suit all application requirements (e.g. decorative lighting fixtures) 2. Lower CRI of CFL may not match requirement for specific applications 3. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely available in the retail market 4. Higher lamp cost
	200W to 500W	1. AHL	1. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely available in the retail market 2. Higher lamp cost
Main Voltage Halogen Reflector Lamps	All wattage	No available replacement	1. Light beam characteristics such as center beam intensity and beam angle are not fully complied.
ELV Halogen Non-reflector Lamps	All wattage	1. AHL	1. AHL are available in similar shape of incandescent lamps. However, most of them need bulk purchase but not widely available in the retail market 2. Higher lamp cost
ELV Halogen Reflector Lamps	All wattage	No available replacement	1. Light beam characteristics such as center beam intensity and beam angle are not fully complied.

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APPENDIX A

Government Policies and Programmes for Lamps in Major Countries

Government Policies and Programme for Lamp in Major Countries

Country	GLS	Halogen Lamp	Reflector Lamp	CFL	Other FL	Metal Halide Lamp	High-pressure Sodium Lamp	HID	Mercury vapour lamp	Remarks
Australia	Mu[4]	Mu[4]	Mu[4]	Mu[1], E[3]	M[2]			Mu		1. MEPS for Compact Fluorescent Lamps (CFLs) - Australia (--) 2. AS/NZS 4782.2:2004: Double-capped fluorescent lamps - Performance specifications - Minimum Energy Performance Standard (MEPS) (10-2004) 3. Energy Smart Product Logo - CFLs (--) 4. MEPS for Incandescent lamp AS/NZS 4934.2 under development and discussion
Canada	C		M1, C	M[2], C, E[4]	M[3], C, E[5]			Mu		1. Mandatory MEPS for Incandescent reflector lamps (01-04-1996) 2. Mandatory MEPS for Compact Fluorescent Lamps and Ballasted Adapters - CFLs (1996)2. Mandatory MEPS for Compact Fluorescent Lamps and Ballasted Adapters (1996) 3. Mandatory MEPS for general service fluorescent lamps (01-02-1996) 4. Energy Star - Compact Fluorescent Light Bulbs (Canada) (--) 5. Environmental Choice Program (ECP) - Lamps (1988)
China				M[1], C, E[5], F	M[1, 2, 3], C, E[6,7], F	Mu, E[8]	M[4], C, E[9]	Mu		1. GB 19044-2003: Limited values of energy efficiency and evaluating values of energy conservation for self-ballast fluorescent lamps (01-09-2003) 2. GB 19415-2003: Limited values of energy efficiency and evaluating values of energy conservation for single-capped fluorescent lamps (2003) 3. GB19043-2003: Limited values of energy efficiency and evaluating values of energy conservation for double-capped fluorescent lamps (01-09-2003) 4. GB 19573-2003, MEPS for high-pressure sodium vapour lamps (01-02-2005) 5. China Energy Conservation Product Certification - Compact Fluorescent Lamps (20-12-2002) 6. China Energy Conservation Product Certification - Single Capped Fluorescent Lamps (--) 7. China Energy Conservation Product Certification - Double-Capped Fluorescent Lamp (--) 8. China Energy Conservation Product Certification - Metal Halide Lamp (--) 9. China Energy Conservation Product Certification - High Pressure Sodium Lamp (--)
EU	C[1]	C[1]	C[1]	C[1], E[2]	C[1], E[2]					1. Commission Directive 98/11/EC (2000) 2. EU Eco-Labelling Programme - Light Bulbs (single) (--)
Japan				M[1], C	M[1], C, E[2,3]			Mu		1. Top Runner Programme 2. Energy Conservation Labelling System - Fluorescent Lamps (21-08-2000) 3. Label Display Program for Retailers - Fluorescent Lamps (--)

Country	GLS	Halogen Lamp	Reflector Lamp	CFL	Other FL	Metal Halide Lamp	High-pressure Sodium Lamp	HID	Mercury vapour lamp	Remarks
Singapore				E[1]						1. Green Labelling Scheme - CFLs -Singapore (07-04-1993)
South Korea	M[1], C[4]			M[3], C[6], E[8,10]	M[2], C[5], E[7,10]	E[9]				1. MEPS for Incandescent Lamps - Korea (01-10-1992) 2. MEPS for Fluorescent Lamps - Korea (01-10-1992) 3. MEPS for Compact Fluorescent Lamps - Korea (01-07-1999) 4. Energy Efficiency Rating Labelling Program for Incandescent Lamps (01-10-1992) 5. Energy Efficiency Rating Labelling Program for Fluorescent Lamps (01-10-1992) 6. Energy Efficiency Rating Labelling Program for Compact Fluorescent Lamps (01-07-1999) 7. High-efficiency Appliance Certification Program for Fluorescent Lamps (1997) 8. High-efficiency Appliance Certification Program - CFLs (1996) 9. Certification of high energy efficiency appliance program for Metal-halide Lamps (--) 10. Korean Eco Label - Fluorescent Lamps (--)
United Kingdom		E[1]		E[2]						1. Energy Saving Recommended - Halogen Bulbs (2006) 2. Energy Saving Recommended - Compact Fluorescent Lamps (GLS shape, stick and candle effect bulbs) (2006)
USA	Mu, C		M[1], C	M[2], C[4], E[5]	M[3], C[4]	Mu	Mu	Mu	Mu	1. Incandescent Lamps - USA (31-10-1995) 2. Compact Fluorescent Lamps - USA (--) 3. Fluorescent Lamps - USA (1994) 4. EnergyGuide - Fluorescent Lamps (1994) 5. ENERGY STAR - Compact Fluorescent Lamps (1999)

Policy/Programme:

M MEPS
C Energy Label (Comparison)
E Energy Label (Endorsement)

Status:

v Voluntary
m Mandatory
u under development

Government Policies and Programme – Control Gears (Ballast)

Country	Associated	Electronic	Magnetic	HL	MVL	FL	MHL	HPS	Remarks
Australia		M, E[3]	M[2], C	Mu	Mu	M[1,2], Cu[4], E[3]	Mu	Mu	1. AS/NZS 4783.2:2002 : Performance of electrical lighting equipment - Ballasts for fluorescent lamps - Energy labelling and minimum energy performance standard requirements (2003) 2. AS/NZS 4783.2:2002 : Performance of electrical lighting equipment - Ballasts for fluorescent lamps - Energy labelling and minimum energy performance standard requirements - Ferromagnetic Ballasts (2003) 3. Environmental Choice Program (ECP) - Ballasts Electronic (1988) 4. Labeling Program for Fluorescent Lamp Ballasts - Australia (--)
Canada		M[1]	M[2], E[3]			M[1,2], E[3]			1. Mandatory MEPS for Fluorescent Lamp Ballasts - Electronic (03-02-1995) 2. Mandatory MEPS for Fluorescent Lamp Ballasts (03-02-1995) 3. Environmental Choice Program (ECP) - Ballasts Magnetic (1988)
China		M[1], E[5]	M[2], E[6]			M[1,2], E[5,6]	Mu[3], E[7]	M[4], E[8]	1. GB 17896-1999 - The limited values of energy efficiency and evaluating values of energy conservation of ballasts for tubular fluorescent lamps (--) 2. GB 17896-1999 - The limited values of energy efficiency and evaluating values of energy conservation of ballasts for tubular fluorescent lamps (Magnetic) (--) 3. Mandatory standard for ballasts for metal halide lamps - China (--) 4. GB 19574-2003: Limiting values of energy efficiency and evaluating values of energy conservation of ballast for high-pressure sodium lamps (01-02-2005) 5. China Energy Conservation Product Certification - Electronic Ballasts For Fluorescent Lamps (--) 6. China Energy Conservation Product Certification - Magnetic Ballasts For Fluorescent Lamps (--) 7. China Energy Conservation Product Certification - Metal Halide Lamp Ballast (--) 8. China Energy Conservation Product Certification - High Pressure Sodium Lamp Ballast (--)
EU			M[1]			M[1], C			1. Directive 2000/55/EC of the European Parliament and of the Council (2004)
Japan						M[1]			1. Top Runner Programme
Singapore		E[1]	E[2]						1. Green Labelling Scheme - Electronic Ballasts - Singapore (2000) 2. Green Labelling Scheme - Magnetic Ballasts - Singapore (2000)
South Korea	M[1], C[4]	M[2], C[5], E[7]	M[3], C[6], E[8]			M[1,2,3], C[4,5,6], E[7,8]	E		1. MEPS for Associated Ballasts - Korea (--) 2. MEPS for Electronic Ballasts - Korea (01-07-1994) 3. MEPS for Magnetic Ballasts - Korea (01-07-1994)

Country	Associated	Electronic	Magnetic	HL	MVL	FL	MHL	HPS	Remarks
									4. Energy Efficiency Rating Labelling Program for Associated Ballasts (--) 5. Energy Efficiency Rating Labelling Program for Electronic Ballasts (01-07-1994) 6. Energy Efficiency Rating Labelling Program for Magnetic Ballasts (01-07-1994) 7. High-efficiency Appliance Certification Program for Electronic Ballasts (1997) 8. High-efficiency Appliance Certification Program for Magnetic Ballasts (1997)
USA		M^1, C^3	M^2		Mu	$M^{1,2}$, C^3, E^3			1. 10 CFR Part 430: Energy Conservation Program for Consumer Products: Electronic Ballasts For Fluorescent Lamps (--) 2. 10 CFR Part 430: Energy Conservation Program for Consumer Products: Fluorescent Lamp Ballasts Energy Conservation Standards (--) 3. EnergyGuide - Electronic Ballasts For Fluorescent Lamps (1994)

Policy/Programme:		Status:	
M	MEPS	v	Voluntary
C	Comparison Label	m	Mandatory
E	Endorsement Label	u	under development

Remarks:

- **Minimum Energy Performance Standards (MEPS)**: Regulatory measures that stipulate minimum efficiency levels or maximum energy-use levels acceptable for products sold in a particular country or region. MEPS is one of the most popular measures applying to lighting components and are typically implemented at national and regional levels.
- **Energy Labels, ratings and certification schemes**: Energy labels show equipment energy use or efficiency as defined using a common performance metric and testing methodology. There are two major types of label: Comparison labels indicate the energy efficiency of a particular model relative to similar models on the market and are usually mandatory; Voluntary Endorsement labels affixed only on models meeting or exceeding a certain efficiency level, indicate models of superior energy efficiency.
- **Building Energy Performance Certification**: Market disclosure of building energy performance is becoming increasingly common, either through mandatory energy-performance certificates or through voluntary rating schemes. Building codes are increasingly being applied to new-build and retrofit lighting systems.
- **Financial and fiscal incentives**: Financial incentives to consumers to purchase energy-efficient equipment and retire older equipment, with the intention of mitigating the first-cost barrier to more efficient lighting. Common incentives are rebate, credits, soft loans and tax deductions.
- **Procurement programmes**: Procurement programmes that seek to increase the efficiency of the equipment installed in the properties and premises.
- **Information and awareness promotion**: Information and promotional activities such as energy saving guides, product directories and awareness-raising campaigns are the most basic methods used to encourage lighting energy efficiency.

END OF REPORT