Policies for emerging technologies: solid state lighting examples from SSL Annex member countries

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Abstract

Every policy-maker knows that setting regulations on emerging and rapidly evolving technologies is difficult. The pace of innovation can be so rapid that it exceeds the natural pace of policy making. And, compounding this problem, new issues and challenges emerge which require careful study to arrive at appropriate responses and interventions. Solid-state lighting, as a new product technology area, is the embodiment of this challenge. Policy-makers seeking to transform their markets and promote more energy-efficient solid-state lighting have to address issues of scope, exemptions, measurement challenges, requirements, and many other qualities and performance features. This paper draws upon the experiences and offers case studies from the IEA 4E SSL Annex[1] member countries who are actively working on energy-efficiency and performance requirements for SSL retrofit lamps and luminaires.

The paper highlights a portfolio of market transformation policy and programme tools used around the world support and sustain the market for high quality, energy-efficient LED products. Across all the key segments of the supply chain, governments and energy-efficiency programmes can play an important role in raising awareness of efficiency opportunities, while helping to build demand for and stimulating supply of quality energy-efficient, quality lighting.

Brief case-studies are offered in this paper highlighting lessons learned and programmes developed across the membership of the SSL Annex. The initiatives are classified into four categories: (1) quality assurance; (2) communication approaches; (3) manufacturing support and (4) incentives for buyers. Sharing these best-practice case studies will hopefully stimulate other governments to take action, and develop their own portfolio of initiatives to promote high-quality LED lighting.

A transition technology – Solid State Lighting

Solid-State Lighting (SSL), and specifically, light emitting diodes (LEDs) have the potential to provide high-quality, energy-efficient light that surpasses the performance of traditional lighting technologies while offering a lower life-cycle cost. In certain markets and applications, LED lamps and luminaires are becoming the main-stream choice, such as with signage displays and directional lamps. And recently, LEDs have been becoming the most common choice in outdoor and street lighting applications.

However, product testing shows a wide variation in the quality and performance of LED products. While some LED products exceed expected performance and market forecasts, others exhibit problems such as colour shifting, flicker, or have significantly shorter life than manufacturer claims. Poor-quality products can undermine consumer confidence and delay

1. The SSL Annex was established in 2010 under the framework of the International Energy Agency's Energy Efficient End-use Equipment (4E) Implementing Agreement to provide advice to its member countries seeking to implement quality assurance programmes for SSL lighting. This international collaboration was established by the governments of Australia, Denmark, France, Japan, The Netherlands, the Republic of Korea, Sweden, United Kingdom and the United States of America. Further information on the 4E SSL Annex is available from: http://ssl.iea-4e.org/.

Figure 1. SSL Annex Quality and Performance Tiers.

LED market growth; thereby reducing the energy and environmental benefits. Furthermore, the state of knowledge of LED technology continues to evolve with the development of new standards and test methods, and research into the impacts of LEDs on people and the environment.

Careful planning combined with the right mix of market transformation policies and programmes can support and encourage uptake of high quality, energy-efficient LED products. Across all the critical segments of the supply chain, governments and efficiency programmes can play an important role in raising awareness of efficiency opportunities with LEDs, helping to build demand for highly efficient and quality products, while stimulating supply of such products.

There is no one-size-fits-all or universally effective policy and programme model for promoting LED market development. The IEA 4E SSL member countries have employed different policy and programme approaches and elements at different times, taking into account the market and regulatory environment in each jurisdiction. These policies and programmes have helped to achieve strategic policy goals, accelerated the rate of LED market development, and impacted consumer preferences and behaviour. These policies and programmes are classified in this paper into four categories: (1) quality assurance; (2) communication approaches; (3) manufacturing support and (4) incentives for buyers.

Quality assurance

LEDs are a relatively new technology that has rapidly increased its market share over the last five years. In this context, quality assurance programmes offer a solution to help ensure the full benefit in the social, environmental and economic aspects of LED lighting. Quality assurance approaches include promoting the sale/procurement of high quality LED products, setting minimum performance levels for sale/procurement, or supporting the evaluation and effectiveness of policies and programmes through for example independent performance testing and reporting.

QUALITY AND PERFORMANCE TIERS

All policy programmes – whether procurement, labelling or regulatory – need to be based on some performance criteria. To support this work, the SSL Annex has prepared voluntary quality and performance tiers[2] to address product attributes such as colour, lifetime, power, and efficacy for common SSL applications. These product performance tiers are a limited number of proposed performance levels, agreed upon by IEA SSL Annex members, which could be utilised by government, non-profit and donor agencies when designing programmes and policies, including mandatory energy performance regulations or high performance specifications. The objective is to provide a set number of levels that can be utilised by programme designers to reduce costs of writing specifications and to facilitate economic advantages for industry/trade. Further, they help minimise compliance costs with SSL programmes and policies. Member countries are not obligated to use the tiers, and they are not international standards.

MINIMUM ENERGY PERFORMANCE STANDARDS FOR LED PRODUCTS

Experience suggests that if a consumer has a negative experience with a poor quality LED lamp, they may subsequently have negative associations with all LED products.[3] To mitigate the risk of "market spoiling" some governments including the European Union, Singapore and Malaysia have established mandatory energy performance standards (MEPS) for LED products. At the time of this paper, other governments like Australia are actively developing their requirements. Following are two examples from the SSL Annex Member governments:

- **Ecodesign Directive for Energy-Related Products (the European Union)**: The EU established obligatory MEPs for LED lamps sold in all EU-member countries under Ecodesign in regulation EU No 1194-2012. Product labelling regulations covering LED lamps and LED modules were issued in EU No 874-2012, and came into effect in 2013.
- **Draft MEPS for LED Lamps and Luminaires (Australia)**: Australia's Equipment Energy Efficiency (E3) Program has released a consultation regulation impact statement (RIS) considering policy options to improve the energy efficiency

2. "Product Performance" webpage published by IEA 4E SSL Annex; viewed 10 January, 2017. Link: http://ssl.iea-4e.org/product-performance.

3. "LED Program Strategies: Synthesizing Recent Research" by Marian D. Goebes, David Douglass-Jaimes, and Michael Mutmansky, TRC Energy Services and Brian Smith, Pacific Gas & Electric; ACEEE Summer Study 2014 Proceedings. Link: http://aceee.org/files/proceedings/2014/data/papers/5-1080.pdf.

of residential and commercial lighting in Australia and New Zealand, including the introduction of LED MEPS in 2018. The RIS consultation paper, along with information on public consultation sessions and how to make a submission are available on Australia's Energy Rating website.[4]

LED PERFORMANCE GUIDELINES AND SPECIFICATIONS

Governments can also lead by example by promoting, specifying and purchasing high-performing LED systems. Procurement of high quality LED lamps for government-owned or -leased facilities and buildings can accelerate the demonstration and uptake of new and high-performing LED products while providing experience to lighting designers and electrical contractors. Green procurement projects can support the government's public image, showing support for energy efficiency policies, creating demand for cutting edge technologies, and demonstrating prudence with public funding. Some procurement-focused projects include:

- **Government Procurement of Efficient LEDs (Korea)**: Korea, for example, has set a goal of 60 % national deployment of LEDs by 2020. By 2014 all public organisations had to replace more than 50 % of their lighting equipment with LED products. In addition, all public organisations shall purchase high-efficiency certified products (Energy Boy labelled, and 1st grade energy efficiency labelled) when making purchases through the public procurement service unless there are compelling reasons to do otherwise.
- **Best Practice Street Lighting Guide Emphasises System Design (Australia)**: Australia commissioned a best practice guide on street lighting, which was provided to the standards committee during a recent standards revision. There is now a minimum energy performance requirement in the Australian standard (e.g., phasing out mercury lamps). A key recommendation is to develop a *design efficiency-rating scheme* to advise stakeholders that are developing tenders. There are quite a few LED designs that are actually rated poorly. The system design is a key point of emphasis, including considering spacing of street lamps.

MARKET MONITORING, VERIFICATION AND ENFORCEMENT

Governments employ market monitoring (e.g., collecting sales data), verification (testing) and enforcement measures (MV&E) to support the effectiveness of or compliance with policies and programmes. A key step to understanding markets and developing policy is to engage and actively work with industry stakeholders, especially for a rapidly developing technology such as LEDs. Governments can take a lead role or work collaboratively to test products for compliance with MEPs requirements or to support voluntary measures. Furthermore, governments can cooperate together and share market monitoring data with one another, to leverage their collective work and improve testing overall. Following are some examples of these MV&E activities:

- **Verification Testing (Australia, Denmark, Sweden)**: These countries regularly test LED products in the market in order to ensure that lighting products, including LEDs, comply with MEPs and labelling requirements. Verification testing is an important tool for policy makers to inform when to establish or update MEPs so that these performance levels reflect current market trends.
- **Collaborative, regional laboratory capacity building and training (Australia, China, United Nations Environment, etc.)**: Supported by the Australian government and the United Nations, the Pacific Monitoring, Verification and Enforcement project (lites.asia)[5] worked to develop the testing capacity and knowledge in the Asian region. The project sponsored laboratory-focused training on LED measurement and testing topics (e.g., photometric measurements, colorimetry, uncertainty evaluation, lighting distribution, calibration of integrating spheres, etc.) as well as regional lighting standards development.

The United Nations Environment (UN Environment) En.lighten programme recently released a series of updated lighting policy focused monitoring, verification and enforcement guides. These guides include topics such as establishing lighting product registration systems, establishing market baselines and conducting market assessments, enforcing lighting regulations, and good practices for testing lighting products and for photometric laboratories.[6]

Communication tools

Consumers often make their lighting purchasing decisions at the retail outlet/shop. With new LED products increasing the number of choices for consumers, informing and guiding consumers towards higher-efficiency alternatives like LEDs at the point-of-sale is important. Some of the LED-related communication and education strategies differ depending on whether the target audience is consumers or professional purchasers/supply chain actors. Government initiatives can help consumers make informed, energy efficient choices at the point of purchase. Governments also assist end-users by providing web-based resources such as databases, fact sheets, lighting design guides, educational videos and other material. Taken together, these resources can support market transformation by educating consumers at the critical stages when they are making a lighting purchase decision.

PRODUCT LABELLING PROGRAMMES

Labelling programmes can be an excellent element of, or compliment to, a communications campaign. Labels can be endorsement labels oriented to consumers, like ENERGY STAR® in the USA, or categorical labels like the European energy label or the Chinese Energy Label which both have label classes that vary with the level of energy performance. Labelling approaches can also support professional stakeholders and commercial lighting markets. Product-labelling programmes include:

4. "Consultation RIS:Lighting", the Energy Rating website of the Australian Government, viewed 10 January 2017. Link: http://www.energyrating.gov.au/consultation/consultation-ris-lighting.

5. Lites.asia website, viewed 10 January 2017. Link: http://www.lites.asia/.

6. UNEP en.lighten initiative, Toolkits and Guides webpage, viewed 10 January 2017. Link: http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx.

- **EU Energy Label (Europe)**: A mandatory, categorical label with seven categories that range from least efficient (E class) to most efficient (A++ class). This regulation (EU No 874/2012) was adopted in 2012 and established label classes for all lighting products in Europe, including luminaires.[7]
- **Chinese Energy Label (China)**: A mandatory, categorical labelling programme launched in China in 2005 with the aim of transforming the Chinese market towards more efficient appliances. By 2014, the programme covered twenty-nine products in five categories, including lighting and LED products, and products from over 9,000 manufacturers.[8]
- **ENERGY STAR® (USA)**: In the US, the voluntary Energy Star programme is used to differentiate the best performing products and allow consumers to quickly identify trusted products. Energy Star LED lamps save consumers money and protect the environment by reducing greenhouse gas emissions: (a) use about 70–90 % less energy than traditional incandescent bulbs; (b) last at least 15 times longer and saves about $80 in electricity costs over its lifetime; (c) meet strict quality and efficiency standards that are tested by accredited labs and certified by a third party; and (d) produce about 70 % less heat, so it's safer to operate and can cut energy costs associated with home cooling.[9]
- **Lighting Facts (USA):** This LED lighting label, developed in 2009 and is sponsored by the U.S. Department of Energy, is intended to promote accurate and consistent reporting of LED performance claims. This effort is intended to provide information to professional lighting buyers, designers, and energy efficiency programmes through an online database. It conveys lamp or luminaire performance information such as lumens, lumens/Watt, Watts, correlated colour temperature, among other performance information to consumers and other audiences. As of March 2017 it includes over 50,000 products.[10]

INTERACTIVE INFORMATION AT POINT-OF-SALE

SSL Annex member countries have also developed tools that provide information at the point of sale that helps them to take in the total ownership cost. Examples include:

- **Lampguiden "the lamp guide" (Sweden)** The smart phone application helps consumers to choose between different LED products, for example by converting Watts into light output (lumens) and showing savings over a 10 year period. Recently, the app was enhanced to allow consumers to receive lighting tips for specific rooms by switching on and off lights. UK, Denmark and Australia have also developed mobile-based lighting applications, based on the Swedish tool.[11]
- **QR Code on Energy Label (China)** To help reach end-use customers, China developed a national voluntary QR code scheme whereby Manufacturers would add a QR code to the existing Chinese Energy Label. The QR code can be scanned with the smart phone and links consumers to a web page platform with all registered product data including efficiency level and functionality.[12]

TRAINING RETAILERS TO IMPROVE COMMUNICATIONS

The point-of-sale is a critical point in the consumer purchase decision process. Retailers and shop-floor sales representatives often serve as on-site advisors to consumers, finding efficient LED lamps that would fit into their fixtures and satisfy their requirements in terms of quality and brightness. Governments therefore have found it helpful to partner with retailers to promote high efficiency products to consumers. Partnership examples include:

- **Lighting Design Training Manual (Australia)**: Specialist stores were identified as a key player and partner to educate homeowners contemplating new lighting systems (e.g., in renovation or major refurbishment situations). Australia developed a lighting training manual focused on lighting design and options, which is available for and promoted to specialist retail lighting stores (with a video and online training module prepared as well).[13]
- **E-training Programme (Denmark)**: The Danish government developed a short (10-minute) e-training programme targeting retail staff. The video covers a range of technical aspects relating to lighting (e.g., colour, lumens, etc.). The purpose of the e-learning is to educate retailers about lighting in order for them to better guide and provide advice to their customers.[14]

INITIATIVES FOCUSED ON PROFESSIONAL LIGHTING

Working with supply chain actors that supply the professional lighting market, including public, commercial and institutional markets, requires a different approach than with consumers. During construction or refurbishment of commercial, public or institutional buildings, lighting experts/designers are usually appointed who prepare lighting designs and specify the equipment to produce the desired effect. To reach these professionals, governments sponsor professional training and/or accreditation programmes, work with local partners including municipalities and universities, develop demonstration projects in large economic areas with free open-house / training,

7. Commission Delegated Regulation (EU) No 874/2012 of 12 July 2012 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires. Link: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:258:0001:0020:EN:PDF.

8. Yang Yu, Jayond Li and Lei Zeng, CLASP, Consumer Comprehension of the China Energy Label and Household Appliance-using Habits in China, Paper presented to EEDAL 2015. Link: https://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/events/EEDAL15/S2_Standards1/eedal15_submission_93.pdf.

9. US Government ENERGY STAR website, "Light Bulbs", viewed 10 January 2017. Link: https://www.energystar.gov/products/lighting_fans/light_bulbs.

10. Lighting Facts website, "about" section, viewed 10 March 2017. http://www.lightingfacts.com/About.

11. Swedish Energy Agency, "Lampguiden" webpage; viewed 10 January 2017. Link: http://www.energimyndigheten.se/energieffektivisering/hemmet/belysning/lampguiden/.

12. Lu Ye, Ai Xin, Li Jiayang and Tian Jianwei, Appliance Labeling for the 21st Century: Introducing QR code for the China Energy Label, paper presented to EEDAL 2015. Link: https://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/events/EEDAL15/S2_Standards1/eedal15_submission_69.pdf.

13. Lighting Retailer Training Guide, The Department of Industry on behalf of the Equipment Energy Efficiency Program, the Commonwealth of Australia, September 2014. Link: http://www.energyrating.gov.au/document/lighting-retailer-training-guide-0.

14. Presentation at SSL Annex Expert meeting by Casper Kofod, 8–10 November 2016, Risø, Denmark.

and develop information campaigns via professional journal and trade exposition channels. Several examples from Annex member countries include:

- **Street Lighting Training Programme (France)**: For over 10 years, the French Agency for Energy and Environment (ADEME) has sponsored a continuous education programme for specifiers and installers of street-lighting (e.g., municipal, institutional, and utility staff). The 3-day programme includes such topics as lighting design and energy efficient technologies including LEDs. The education programme has contributed to a steady increase in LEDs in street lighting applications in France, which rose from less than 1 % penetration in 2014 to over 2 % in 2015. [15]
- **Municipal Energy Advisors Programme (Sweden)**: The Swedish Energy Agency dedicates a lot of effort to educating consumers, municipalities, lighting designers, specifiers, and retailers. Municipalities themselves are large energy users and also key influencers with local businesses and trades. The programme includes topics such as lighting technology options, performance considerations such as warranty issues, consumer protection laws, electrical safety, and EMC compatibility.[16]

Promoting LED lamps through incentives

Incentives in the form of financial incentives to help buy down the higher cost of LEDs, or in the form of give-away type programmes are instruments available to promote accelerated uptake of LED products. This section presents government incentives for households and professional applications.

- **Household: Utility Rebate Schemes (USA and Australia)**: Some electric utilities in the United States are required by the utility regulator to work with their customers to help promote end-use energy-efficiency. Some of these programmes have focused on lighting, and specifically the provision of rebates and coupons, or bulk-procurement schemes, all aimed at reducing the first-cost barrier to LED lighting. Similar programmes are also run in several Australian States, such as the New South Wales Energy Savings Scheme[17], the Victorian Energy Efficiency Target[18] and the Australian Capital Territory Energy Efficiency Improvement Scheme[19].
- **Professional: Tax Incentives for High Efficiency LEDs (Japan)**: In 2011, Japan put in place a tax incentive scheme for energy load reduction, to reform the energy supply structure, and contribute to emissions goals. Small businesses could apply either a 30 % depreciation deduction or a 7 % tax exemption for installing high efficiency LEDs (greater than or equal to 90 lm/W). To implement the scheme, the Ministry of Economy, Trade and Industry partnered with the Japan Lighting Manufacturing Association (JLMA). JLMA is responsible for coordinating with manufacturers and approving the construction industry applications, as well as to issue certificates to confirm tax benefits. [20]

Supporting domestic manufacturers

Governments involved in the SSL Annex recognised the emergence of LEDs as an opportunity for national business growth and development. Supporting research and developing domestic intellectual property (IP) recognises the adage that "the science of today is the surplus of tomorrow".

PUBLIC INVESTMENT IN NATIONAL LED BUSINESS

The US, Japan, Korea and China have invested in LED research and manufacturing to build their domestic industry and patent base, which is helping to position these economies as leading suppliers of LEDs. One approach governments can consider is to establish business incubators which work to encourage small and medium size enterprises entering the market. The investment in LED business can be for example tax holidays or establishing green tech revolving funds that provide low interest loans or start-up capital to develop an idea or approach.

There are many stages in the LED product supply chain ranging from chip manufacturing through modules, drivers, optical design and assembly, and finally producing the finished product. Companies with some competitive intellectual property position can compete in any stage of the supply chain, whether it's business-to-business or business to consumer.

- **Tax breaks and financial aid (Korea)**: Korea offers tax advantages for suppliers who make energy efficiency investments and subsidies for testing fees in support of the Korean high-efficiency certification programmes.
- **R&D support (USA)**: The U.S. DOE has funded some 230 solid-state lighting R&D projects since 2000. The programme has resulted in 245 patents and millions of LED products on the market that can be attributed at least in part to DOE funding. Funding has gone to a wide range of organisations, including both large and small domestic manufacturers. DOE is guided by the R&D Plan, which outlines R&D challenges and market challenges. DOE plans to focus on several key LED R&D challenges going forward, which were identified as priorities based on stakeholder meetings.

AWARDS AND PROGRAMMES TO PROMOTE QUALITY PRODUCT DEVELOPMENT

Beyond financial incentives and investments, governments can offer manufacturer or product recognition to reward innovation through for example design competitions or voluntary certification programmes. Competitions and other forms of recognition, especially in collaboration with industry and other partners, can accelerate LED innovation while helping to raise

15. Personal Communication, French experts Georges Zissis and Christophe Martinsons at SSL Annex Experts Meetings in Beijing April 2016 and Denmark November 2016.

16. Presentation at SSL Annex Experts Meeting in Risø, Denmark, 8–10 November 2016 by Annex expert Jonas Pettersson.

17. The New South Wales Energy Savings Scheme: http://www.ess.nsw.gov.au/Projects_and_equipment/Lighting_Technologies.

18. The Victorian Energy Efficiency Target: http://www.veet.vic.gov.au/.

19. The Australian Capital Territory Energy Efficiency Improvement Scheme: http://www.environment.act.gov.au/energy/smarter-use-of-energy/energy_efficiency_improvement_scheme_eeis.

20. Presentation by Hiroaki KURIHARA, NEDO at SSL Annex Expert meeting in Seoul, Korea. 4–6 September 2013.

Table 1. Policy Categories and Programmes Undertaken by SSL Annex Member Countries.

Policy Category	Examples
Quality assurance	Minimum energy performance standards (MEPS) Voluntary performance specifications for procurement and quality assurance Monitoring, verification and enforcement programmes/regimes
Communication approaches	Labelling programmes Retailer partnerships Procurement and purchaser education and training
Manufacturing support	Financial incentives including tax incentives Research and development support/funding Standards and testing development Recognition programmes
Incentives for end users	Financial incentives for consumers/businesses Product give-aways

awareness of the highest quality and energy efficient products within a certain category.

- **L-Prize Competition (USA)**: The Energy Department established the L Prize competition to spur development of replacement technologies for two common, inefficient technologies: 60 W incandescent lamps, and PAR38 halogen lamps. The L Prize for the 60 W incandescent replacement category was awarded in August 2011, including a US$10 million cash prize. L Prize winning manufacturers are also eligible for government procurement contracts, utility programs, and other incentives. [21]
- **SEAD Global Efficiency Medal (Global)**[22]: A global award for the most efficient lamps and luminaires, the "SEAD Global Efficiency Medal" award is given by the Clean Energy Ministerial's Super-efficient Equipment and Appliance Deployment (SEAD) initiative. It demonstrates the levels of efficiency that are possible today while maintaining high quality in terms of light output and product performance.
- **The Global Lighting Challenge**[23]: The Global Lighting Challenge is a race to reach cumulative global sales of 10 billion high- efficiency, high-quality, and affordable advanced lighting products, such as light-emitting diode lamps. This race will showcase the ways businesses, governments, and other public-sector leaders are taking action to accelerate this transition. Representatives from 12 countries and the European Commission endorsed the launch of the Challenge at the Sixth Clean Energy Ministerial in May 2015.
- **Sweden's Belysningsutmaningen** . Sweden is running a national programme that mirrors the Global Lighting Challenge called "Belysningsutmaningen[24]". Launched in May 2016, this initiative brings together manufacturers, retailers, procurers and other interested stakeholders have endorsed or signed up to specific commitments (like in the GLC). The group meet on a regular basis, hosted by the Swedish Energy Agency, exchanging experiences, attending seminars on technology development and new knowledge about lighting concepts (like new metrics for CRI and flicker). Some stakeholders also arrange local events in the name of "Belysningsutmaningen" where they can meet. Through these activities the interest and knowledge of new lighting solutions is promoted.

SUPPORT TESTING STANDARDS AND LABORATORY ACCREDITATION

Governments can also help to support and accelerate the national/international LED test standards process and standardisation in support of high quality and energy efficient products. Following the publication of "Test Method for LED Lamps, LED Luminaires and LED Modules" by the International Commission on Illumination (CIE S 025/E:2015), governments can also facilitate the accreditation of test laboratories to this new international measurement standard. Examples of how governments have been engaged in test standard development include:

- **Interlaboratory Comparison**[25]: In September 2014, the IEA 4E SSL Annex published a Final Report on an LED lighting product measurement comparison of over 110 lighting test labs from around the world. This comparison, called the 2013 Interlaboratory Comparison, was designed to (1) help support harmonisation of SSL testing around the world and (2) help establish a common proficiency test[26] for accreditation programmes aimed at different regional test methods. The follow-up 2017 Inter laboratory Comparison, focusing on Gonio photometer using CIE S 025, was announced in January 2017 and is intended to provide a proficiency testing opportunity for laboratories, encouraging uptake of the new international standard.[27]
- **Harmonising with International Standards**: In Europe, the regional standardisation body, CEN/CENELEC re-

21. US DOE's L-Prize web site, visited 10 March 2017. http://www.lightingprize.org.

22. SEAD Global Efficiency Medal, Lighting Awards webpage. Viewed 10 January 2017. Link: http://www.superefficient.org/Global-Efficiency-Medal/Lighting-Awards.

23. The Global Lighting Challenge: http://www.globallightingchallenge.org.

24. http://www.energimyndigheten.se/belysningsutmaningen/ (Only in Swedish.)

25. "Solid State Lighting Annex: 2013 Interlaboratory Comparison, Final Report", viewed 10 January 2017. Link: http://ssl.iea-4e.org/news/2013-ic-final-report.

26. Proficiency testing is used to establish whether a lab can be accredited for testing against a specific standard.

27. Pre-Announcement IEA 4E SSL Annex 2017 Interlaboratory Comparison of Goniophotometer Measurements (IC 2017), IEA 4E SSL Annex, Jan 2017. Link: http://ssl.iea-4e.org/news/pre-announcement-ic-2017.

viewed and adopted the CIE S 025[28] Test Method for LED Lamps, LED Luminaires and LED Modules as a European Norm, EN 13032-4. This process of harmonisation ensures that European testing standards are consistent with international best practice for the measurement of LED lighting products.

Conclusions and recommendations

There is no one-size-fits-all policy or programmatic model, thus countries have developed portfolios of policy and programme tools that work to support and sustain the market for high quality, energy efficient LEDs. Across all the critical segments of the supply chain, governments and energy efficiency programmes can play an important role in raising awareness of efficiency opportunities and limitations of LEDs, while helping to build demand for and stimulating supply of the energy efficient and quality products.

The key themes and findings that are common programme elements of LED market transformation programmes and can be found in the SSL Annex are shown in Table 1. Cooperation and knowledge sharing is central to effective support structures for LED market development. Through this sharing of information between national governments, industry, energy efficiency programmes, local government stakeholders and non-profit organisations, the LED market can develop along a high-efficiency, high-quality pathway sustaining energy savings and other benefits.

References and acknowledgements

All references are given in full as they appear in each footnote, and have not been listed here again for space reasons. In addition, the national IEA 4E SSL Annex Experts have been meeting twice yearly for three day meetings. During these meetings each national Expert has presented his or her country's recent developments and programmes for promoting LED technologies. This paper is based on numerous presentations and ongoing personal communication during and between meetings with these national Experts.

28. Link to the CIE S 025 Standard: http://cie.co.at/index.php?i_ca_id=973.