Asia-Pacific
Economic Cooperation

Establishing Educational Pathways for Lighting Best Practices: An APEC Regional Collaboration with University Lighting Centers and Research Institutions

Final Report

Energy Working Group

February 2017

APEC Project: EWG 06 2015A

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APEC#217-RE-03.3.

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INTRODUCTION

Lighting consumes about 25% of world energy use, but this figure can be as high as 33% in developing economies. Due to pressing climate goals, many APEC economies are currently struggling to develop zero net energy (ZNE) roadmaps that rely heavily on achieving deep energy saving in an aging building stock. Retrofitting the existing building stock with highly efficient lighting is one of the most effective ways to achieve deep energy savings and rapidly reduce our dependence on fossil fuels.

Buildings' energy consumption constitutes one of the largest contributions to greenhouse gas emissions and has been targeted by many APEC economies as a priority opportunity. However, there exists a considerable lack of knowledge on how to best achieve these deep energy saving and which strategies and practices should be employed with finite public investment. Unifying lighting best practices, and supporting educational program has the potential to significantly increase the rate at which advanced lighting solutions are adopted across in developing economies, decreasing the overall energy use.

This project was a continuing effort as suggested by the result obtained at the US-led, APEC funded workshop on Establishing Lighting Center in the APEC Region in 2013 (EWG 14 2012A), hosted by King Mongkut's University of Technology Thonburi (KMUTT), Bangkok, Thailand. It was agreed that there should be further collaborations among university-based lighting research and design centers in the APEC region on education and training of building professionals to transfer knowledge on lighting best practices. Thus two sequential workshops were proposed with the objectives of identifying barriers and lighting best practices as well as developing effective educational pathways and course plan that can reach respective audiences.

The first workshop, hosted by KMUTT, was held on 2-3 June 2016 in Bangkok. It was organized around a series of presentations of best practices for achieving deep lighting energy savings for both retrofit and new design of buildings. Four main groups of best practices were identified: 1) adaptive lighting/ demand-response lighting 2) daylighting for the tropics 3) advanced design and specifications 4) task-ambient lighting for offices. These were used as a basis for the roundtable discussions, which helped identifying the educational stakeholders and critical barriers many of which involved knowledge or experience gaps in the lighting field. Recommendations have been made on possible education pathways and initial structure of a common learning platform. The industry participants also reiterated their strong support for continuing the educational portion of the program. These results contributed to the organization of the second workshop in Shanghai.

The second workshop was co-hosted by Tongji University, Shanghai, People Republic of China on 15-16 September 2016. Seventeen people from 7 APEC economies attended the workshop. Over the two-day workshop the invited experts reviewed the list of lighting best practices and agreed on potential educational pathways proposed from the workshop in Bangkok. The break out groups were working on the structure and work flow for an effective educational program that would be suitable for professional audiences in order to support the ZNE policies.

Subsequently, an educational webpage resource was developed to provide a common platform where project partners could contribute on training materials, case studies and updates on current research. There was also a discussion on initiating a regular seminar with the aim to share and exchange on lighting best practice projects and applied research.

Post-workshop activities included evolving and refining the course structure and guidelines in order to achieve learning objectives. As the Lighting Research and Innovation Centre at KMUTT has regularly offered training programs for building professionals, a pilot test was conducted with the daylighting design course. Part of the contents from the APEC project was integrated into the existing training programs in order to test and refine the curriculum.

CHAPTER 1:
IDENTIFYING LIGHTING BEST PRACTICES

According to an education program development process, first essential steps are need assessment and planning session. These were achieved by the pre-workshop surveys and the first workshop in Bangkok. Lighting experts and key stakeholders were invited to share their experiences as well as to discuss on effective educational pathways for lighting best practices in the APEC region. This chapter presents a sequential review of the key presentations and outcomes from the first workshop. These include assessment of lighting best practices and potential attributes of effective educational pathways for the second workshop.

1.1 THE FIRST WORKSHOP: OBJECTIVES AND PROCEDURE

The first of the two APEC-funded lighting experts workshop was held successfully on 2-3 June 2016, at Chatrium Hotel Riverside, Bangkok, Thailand. It was hosted by King Mongkut's University of Technology Thonburi and University of California at Davis; and co-hosted by the Electricity Generating Authority of Thailand (EGAT) and National Science and Technology Development Agency (NSTDA). Sixty-five people attended the workshop and around thirty percent were female. Twenty Thai and foreign speakers and participants from eleven APEC economies were invited to present and actively involved in group discussions over the two-day workshop. These included Australia; China; Hong Kong, China; Indonesia; Japan; Malaysia; the Philippines; Singapore; Thailand; the United States; and Viet Nam.

Objectives
1. Identify key best practices involving policies and opportunities technologies or design approaches that can achieve deep energy saving in the lighting of buildings
2. Learn from effective collaboration models among stakeholders and strategies of the successful implementation of policies and projects
3. Make recommendations on unified lighting best practices that can be applied to the design and retrofitting of buildings in the APEC region

Conducting the Workshop

Prior to the workshop, surveys on current needs and lighting best practices were conducted in Hong Kong, China; Indonesia; Malaysia; and Thailand by semi-structured interviews and followed up short questionnaire. The purposes were to compile an initial list of lighting best practices and case studies. From the interviews there seemed to be interests on providing information of projects which considered best practices, i.e. save some 50% of the lighting energy use compared to standard practice.

However, there were few filled out questionnaires returned from the consultants. Thus the information presented here was mainly obtained during the workshop. Initially Professors Chuntamara, Siminovitch and Luoxi Hao conducted a series of pre-workshop planning meetings with the objective of reviewing and finalizing the process for the initial workshop. This involved finalizing the agenda with a focus on how the workshop presentations and breakout session would work as a cohesive structure. We also engaged with our partners at Singapore Lighting Technology and Design Centre (SLTDC) developing the final structure for these tasks.

The workshop structure was based on having a series of presentations from representative countries throughout the APEC region with a focus on best practices and case studies. During these two days of presentations we would abstract and condense example recommended best practices for inclusion on the first draft list. This listing as a draft would be a dynamic process and modified throughout the first and second day. At the end of the first session the plan was to present an overview of the draft best practices as recorded from the presentations.

The three co-chairs from China; Thailand; and the United States reviewed the presentations at the end of the first day to summarize and condense the best practices into a shortlist of 16 overarch-ing best practices. These best practices were then being sorted into specific concentration areas (for each breakout groups). We also asked the workshop participants to review the presentations and to provide any additional insights relative to best practices that were not clearly articulated or developed in the first day. This gave the opportunity for individuals to discuss develop and brainstorm additional ideas evening hours of the first day.

On the second day, the draft list for best practices was presented before the breakout discussion sessions. The participants were divided into three different groups, each of which comprised a cross-section of stakeholders that represented academia, utilities, government and professional/ industry organizations. We also developed five different issues/questions that the breakout groups were to discuss including:

1. Energy-saving potential
2. Scalability-relative to the market
3. Policy fit -codes and standards
4. Barriers-issues preventing broad adoption
5. Educational stakeholders-people/organizations
6. Potential educational programs.

Each working group took 5-6 of best practices and develop a more in depth narrative based on the five questions. The focus of the breakouts was to concentrate on the associated barriers and potential educational pathways and stakeholders to help inform the Shanghai workshop. The questions related to energy-saving potential and scalability were included more to ensure and test the suggestions as indeed qualifying for best practice status. The concept was that designs or technology that are not readily scalable or have a large energy-saving potential should not be included in this initial list of high ranking best practices.

Our intention was to have a broad cross-section of lighting stakeholders to review and prioritize a relatively short list of best practice concepts that could be moved forward in a broader educational program. After the breakout group discussions, each group then presented the key results of their discussion. Comments and questions were then recorded with the key focus on barriers, educational stakeholders and potential educational programs to help inform the workshop in Shanghai.

1.2 KEY ISSUES RELATING TO BEST PRACTICES

This section summarizes key issues from the presentations and discussions by 1) the lighting experts and representatives from government, utilities, university lighting research centers 2) lighting consultants and green building professionals and 3) representatives of building owners / facility managers as well as manufacturers and suppliers.

1.2.1 Zero-net Energy Policies and Activities in the APEC Region

The workshop started with an introductory presentation from the president of KMUTT, Assoc. Prof. Sakarindr Bhumiratana; this presentation included general welcoming comments with a focus on the importance of APEC universities and research institutions working together on critical problems such as climate change and energy efficiency. He also commented on some of the leadership activities ongoing in Thailand with the focus on sustainability, climate change and energy efficiency. Subsequently, Assoc. Prof. Bundit Fungthammasan, the vice president of KMUTT, also presented a broad overview of the current energy efficiency programs, objectives and activities ongoing in Thailand. He reviewed the past, current and future policy objectives related to climate change and the importance of developing improved efficiency activities.

For Thailand, following the APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development in 2011 that, collectively, the members would reduce the energy intensity (EI) by 45% by 2035 compared to that of 2005, Thailand has established its energy efficiency goal and revised it in 2015. The revised plan (in draft form) aims to reduce 30% of the energy intensity by 2036 compared to that of 2010. To achieve this new goal, the building sector is one of the main targets of the Energy Efficiency Plan (EEP 2015).

The Ministry of Energy aims to reduce the energy used in both retrofit and new buildings by tightening the building codes, promoting the use of energy efficiency labeled products and green certifications by LEED or TREES (by Thai Green Building Institute) as well as the construction of net-zero energy buildings. There are financial incentives and technical supports through several schemes, particularly for government and state-enterprise facilities. As part of the voluntary program, energy efficient lighting by using LED technology is one of the main strategies; it aims to replace with 2 millions LED lamps in government buildings and 3 millions LED lamps for public roads and streets, which partly have been implemented by the Provincial Electricity Authority (PEA).

The revised plan also proposed that the electricity producers and providers would be obliged to help their customers with energy efficiency (Energy Efficiency Resource Standard - EERS). As this is a new strategy for Thailand, it still needs a further study on its implementation. Metropolitan Electricity Authority (MEA), the electricity distributor for Bangkok metropolitan area, has collaborated with Chulalongkorn University to investigate and demonstrate the potential savings of smart street lighting technology near MEA head quarter in central Bangkok.

Mr. Jirasak Mantharngkul, Director of Demand Side Management and Planning Division, Electricity Generating Authority of Thailand (EGAT) provided an overview of the ongoing activities in the demand side management arena in Thailand. EGAT has implemented the energy efficient labeling scheme for electrical appliances (No. 5 Label) for 23 years and recently added LED replacement lamps, LED low-bay and high-bay luminaire on its list. His presentation included a number of examples associated with high-efficiency components, fixtures, LED lamps and street lighting applications as opportunities for significant savings. His recommended best practices were to focus on high-efficiency components and systems for building applications, particularly the ones that can support *demand-response* strategies.

In addition to these policies and strategies, the government and utilities also support applied lighting research and knowledge transfer to practitioners. Dr. Chanyaporn Chuntamara gave an overview of current key research at KMUTT's Lighting Research and Innovation Centre (LRIC) on task-ambient lighting and smart street lighting, both of which will be completed later in 2017. After the main experimental studies, it was planned to use the installations as demonstration sites. Apart from these demonstration facilities, LRIC is completing its new lighting laboratory and the artificial sun for teaching and training of design professionals.

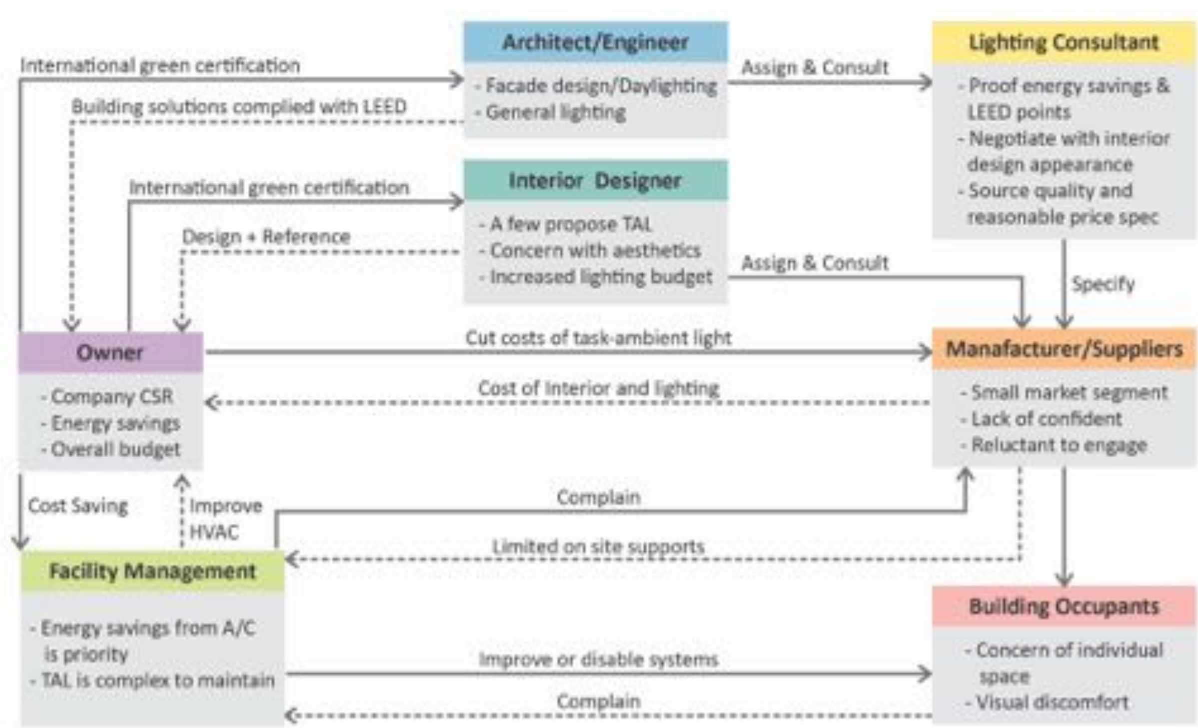

Figure 1 Social mechanism of implementing task-ambient lighting in Thailand

An interim result from the task-ambient lighting research to promote its adoption for office application in Thailand, in-depth interviews and field surveys as well as usability testing of available products were conducted. The diagram (Figure 1) shows the *social mechanism*, the relationship among key stakeholders involved in the policies, decision-making, design and implementing task-ambient lighting strategies in Thailand. Figure 2 and 3 show the condition of office building that successfully utilized daylight-harvesting and task-ambient lighting strategies, resulting in deep energy savings and satisfied occupants. The results gave an insight on social and knowledge barriers as well as the importance of an integrative approach that considers both task-ambient lighting and daylighting to minimize thermal and visual discomfort.

Figure 2 Lightshelves at perimeter office

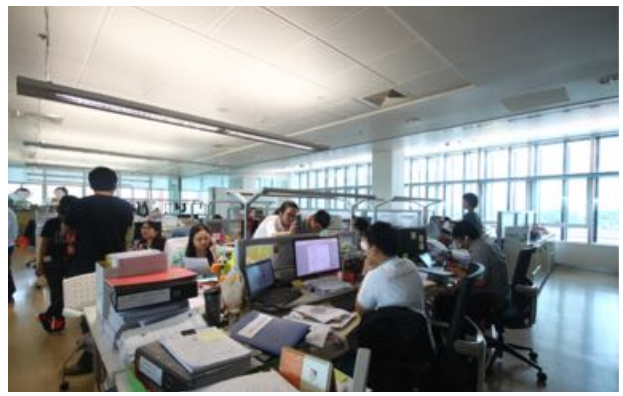

Figure 3 Daylight and task-light in open-plan

Singapore government has also made a commitment to reduce energy and greenhouse gas emissions; the goal is to reduce its emissions intensity by 36% from the 2005 level by 2030. All types of buildings use nearly 50% of electricity consumption and contribute to some 25% of all emissions. Lighting uses 15-20% of the overall electricity use. Mr. Jeffery Neng, Environmental Sustainability Group Deputy Director, the Building and Construction Authority (BCA) gave an overview of Singapore's Green Mark which comprises a number of rating tools that rate the built environment for its energy and water use and environmental impact.

The aim is to have 80% of buildings in Singapore certified by 2030; as of 2016 there are some 2,800 Green Mark projects, accounting for 31% of all building stock. Four main categories include 1) New Buildings 2) Existing Buildings 3) User Centric for specific applications 4) Districts, Parks, and Infrastructure. Innovative daylighting and daylight harvesting for the tropics as well as design, installation, and commissioning of energy efficient lighting and controls are part of the green mark ratings. These best practices are demonstrated in the BCA's three-story Academy campus building - also the first retrofitted zero-net energy building in Singapore. Figure 4a-ab show daylighting strategies using horizontal and vertical light pipes respectively and Figure 5 shows the fenestration design, external shadings and green walls. Currently BCA has collaborated with SinberBest to upgrade the lower floor of the Academy into the 'Living Lab', installing more advanced lighting design and control strategies (Figure 6).

Figure 4a-ab Horizontal and vertical light guides

Figure 5 External shadings and green walls

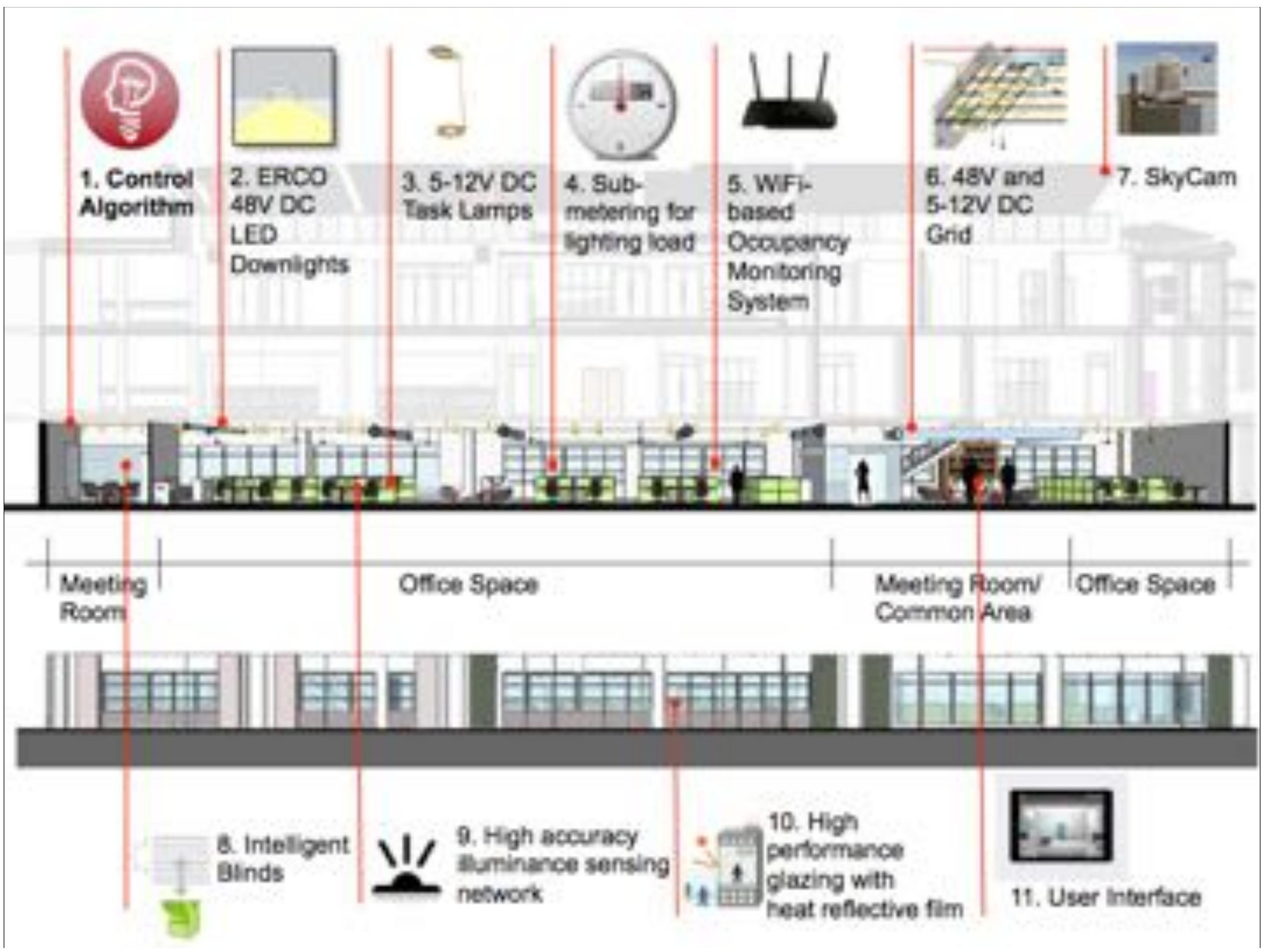

Figure 6 Advanced lighting strategies at the BCA Academy living lab ZEB Plus

In July 2016, BCA launched SkyLab[1] to support research and knowledge transfer on sustainable buildings and lighting in the tropics. The BCA SkyLab is a 360-degree revolving laboratory, developed in collaboration with the Lawrence Berkeley National Laboratory. It is capable of testing a wide range of energy efficiency technologies, including ACMV, lighting (e.g. addressable LED, day-lighting, etc.), facade (e.g. Low-E glazing, sun shading, etc), plug load and control strategies. It features two configurable test compartments (i.e. the reference cell and the test cell) equipped with 200 sensors that enable comparison testing of design solutions and performance validation of technologies, against a base line or benchmark code (see Figure 7-8).

Figure 7 Exterior of the BCA SkyLab

Figure 8 Rendering of the test room with sensors

The BCA is working with the United National Environment Program's Nationally Appropriate Mitigation Actions (NAMA) program for the building sector in Asia to help communicate findings from its Green Mark studies—and possibly SkyLab, down the line—with public and private agencies in Indonesia; the Philippines; Thailand; and Viet Nam, which are among the current and potential markets for Singapore's Green Mark certification. The NAMA agreements will include national plans for reducing greenhouse gas emissions.

In addition to the BCA's platform for knowledge sharing and transfer, BCA and Singapore Green Building Council (SGBC) have established Singapore Lighting Technology and Design Centre (SLTDC) in 2013. Dr. Chien Szu-Cheng gave an overview of SLTDC's vision and ongoing activities with a focus on both policy and best practices. SinBerBest is a strategic partner in conducting advanced intelligent building and lighting research and engaged in knowledge transfer to designers and building professionals. Current focus is to develop advanced lighting control systems capable of delivering low-energy lighting solutions, while maintaining the indoor environmental quality and comfort for the building occupant. It also works closely with government agencies and industry partners. It has advanced facilities for lighting research addressing tropical climate-responsive: Translucent concrete for daylight harvesting, Daylight emulator, Sky scanner, and full-scaled test-bed for intelligent integrative lighting control system.

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[1]The BCA SkyLab is a state-of-the-art rotatable test facility pivotal to developing innovative energy efficient building technologies. The facility is modelled after the Lawrence Berkeley National Laboratory's FLEXLAB.

Other applied research on lighting best practices in the APEC region included a study on the application of LED lighting for residential buildings presented by Prof. Dr. Nianyu Zou, Research Institute of Photonics and leader of Optical engineering faculty, Dalian Polytechnic University, Dalian, China. She is the Chinese representative leader of co-operation research project on residential lighting between China; Japan; and Korea. Prof. Louxi Hao from the Lighting Environment Laboratory, Tongji University in Shanghai, also involved in several key lighting research and implementation of LED lighting for urban areas that aimed to reduce wasteful lighting energy, resulting in light pollution. Figure 9 and 10 show the experimental room for research, teaching and training facilities for electric lighting and daylighting at Tongji University and Tsinghua University (Beijing, China) respectively.

Figure 9 Experiment room at Tongji

Figure 10 Artificial sky and sun simulator at Tsinghua

In Australia, according to the Australian zero carbon building plan (August 2013), it was estimated that the electrical energy savings approximately 20 TWh per year was possible with the recommended upgrades. This reduction would be greater than the amount of electricity produced by one continuously operating Hazelwood-sized coal fired power station (Latrobe Valley, Victoria). The use of LED for all lighting applications and better shading for buildings are suggested as a way to achieve this goal. It was also suggested that *"there are no technical barriers to achieving zero emissions from Australia's buildings within a decade. The Buildings Plan proposes: energy efficiency retrofits of existing buildings …"* (source: http://bze.org.au/buildings-plan/).

Another perspective on lighting best practices and education was from Professor Warren Julian who have had extensive experiences in lighting education and training of lighting and design professionals in Australia and APEC region including Hong Kong, China; Malaysia; and Thailand. He emphasized on the importance of quality lighting design on the energy efficiency equation, giving an overview of the importance of integrated design in developing better thought of best practices with a focus on quality and lighting design issues. Prof. Julian presented a series of potential best practices that included developing performance-based standards, improved design metrics and a focus on user based user-friendly control systems.

Professor Alan Suleiman represented Sacramento Municipal Utility District (SMUD) and Sacramento State University presented a cross section of ongoing lighting demonstration programs with a focus on deep energy savings. His presentation also included a strong policy perspective and its impact on supporting Energy efficiency activities in California. Specific examples included policy support for control systems, sensors and LED technology. As advanced controls can save 50 to 75% lighting energy savings, SMUD supported strongly the opportunity associated with sensor based controls for public spaces both internally and externally in buildings. For commercial buildings, the newest control technologies offer flexibility to suit the business style and needs. The lighting system can be controlled onsite or remotely from internet based interfaces, like smart phone, or computer terminals. Automated demand response capability can be incorporated into the system.

SMUD offers rebates on qualifying LEDs through the Express Energy Solutions (EES) program, including 1) Interior Lighting Fixtures and Lamp Replacement 2) Exterior Lighting and 3) Advanced Lighting Controls. To encourage medium to large size commercial customers to adopt the advanced controls, SMUD set the energy efficiency incentives at $0.25 per kWh saved (up to a maximum of $100,000 or 70% of the total project cost). This is based on a condition that the project apply for incentive schemes must use qualified products list (2015).

Professor Michael Siminovitch then gave his presentation on best practices representing California's perspective on zero net energy. His presentation included a cross-section of lighting efficiency projects case studies and introduced a range of best practices tested and implemented at California Lighting Technology Center (CLTC) and various demonstration sites (Table 1). These best practices included adaptive bi-level lighting for stairwells and corridors and adaptive sensor base exterior/public lighting (see Figure 11-13). This involves reducing power during periods of inactivity using advanced sensor technology. Case studies presented from the work California indicate 40 to 50% savings with reducing lighting during periods of vacancy or inactivity. In addition to the adaptive lighting strategies, task-ambient lighting with added layer of vertical lighting was also proposed for some 56% in office application compared to the standard practice ASHRAE 90.1- 2007 (see Figure 14).

Table 1 Comparison of field demonstration savings

Research Site	Site Type	Baseline Source Type	Retrofit Source Type	Control Strategy	Total Energy Savings (%)
City of Chula Vista	Street	HPS	LED	Fixtures + Network	55%
City of San Diego	Street	HPS	LED/Induction	Fixtures + Network	59%
UC Davis	Area	HPS/MH	LED/Induction	Fixtures + Network + Occ.	89%
UC Irvine	Street	Induction	LED	Fixtures + Network + Occ.	Pending
City of Davis	Street	HPS	LED	Network + Occupancy Sensing	27% - 42%
VacaValley Hospital	Area	Induction	LED	Fixtures + Network + Occ.	66%

Figure 11 Demonstration of networked street lighting controls at City of Davis
(Photo Credit: California Lighting Technology Center)

Figure 12 and 13 Demonstration of networked pathways lighting controls at UC Davis
(Photo Credit: California Lighting Technology Center)

Figure 14 Task/vertical/ambient lighting and energy saving potential
(Source: California Lighting Technology Center)

1.2.2 Experiences Shared by Building Professionals

Lighting and green building consultants also shared their professional experiences on lighting best practices that have been implemented in real projects the APEC region. These are valuable information and gave an insight on some of the technical and social barriers.

Mr. Gregers Reimann (IEN Consultants, Malaysia) presentation focused on integrated design of daylighting for the tropics and task ambient lighting solutions. While there are great potentials for using daylight in the tropics, he suggested that misconceptions about associated heat with daylight from some facility managers and designers as well as the general avoidance of sunlight to protect the skin are among the knowledge and social barriers. His presentation also included some novel daylight distribution systems with the objective of reducing glare and maximizing daylight penetration within office applications (see Figure 15-17). His suggested best practice focused on integrated daylighting design with glare control devices.

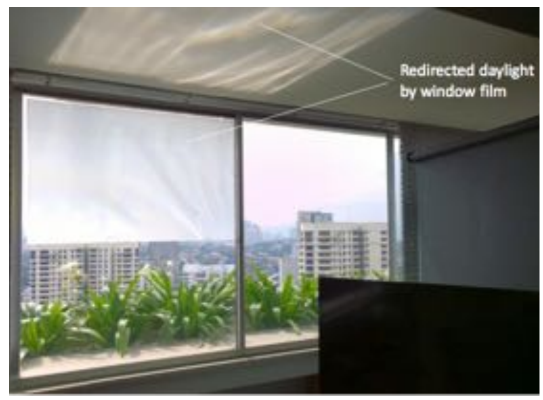

Figure 15 Split-level window and integrated blinds
Figure 16 Film for redirecting daylight
(Source: www.ien.com.my)

Figure 17 Full-scaled mock up of horizontal light trough for high-rise office buildings
(Source: www.ien.com.my)

These are similar to Dr. Michael Hirning's views on the importance of integrating glare considerations in the design of daylight applications. His presentation concentrated on the development of a glare assessment tool (formulae) to help inform the application of daylighting best practices. His primary recommendation for best practice was the integration of appropriate glare control devices in the application of daylighting. There was also strong recommendation for the development and an appropriate glare model in daylighting for the tropics. Based on his previous study and development of the Unified Glare Probability (UGP), under clear skies in Brisbane, Australia, he has validated the UGP using post-occupancy surveys under different sky conditions, building types and demographics in the tropical climate of Kuala Lumpur, Malaysia.

Ms. Ying Ching Hui, an electrical engineer from Aurecon Group, shared some cases of lighting energy savings, while maintaining the lighting quality as recommended by Australian lighting standard (AS/NZS 1680.2.1:2008 Interior and workplace lighting – Specific applications – Circulation spaces and other general areas). Her presentation had a strong practices perspective with a series of real case studies demonstrating the energy saving potential associated with LED lighting (Table 2), task ambient and daylighting strategies. Her recommended best practices focused on task ambient, solid state lighting and high-efficiency lighting devices, with specific reference to luminaire efficiency and control gear efficiency. Though lighting specifiers should consider using quality product with high efficacy and also colour quality to avoid dissatisfaction and discomfort such as colour shift of LED products as shown in Figure 18.

Table 2 Energy savings and CO2 emission reduction with LED retrofit

	T8 (36W)	T5 (28W)	2013 LED (40W)	2016 LED (23W)
Spacing	2.4 m x 2.4m	2.4 m x 2.4m	2.4 m x 3m	2.4 m x 3m
Quantity	973	973	762	762
Lighting Power Density (W/m²)	7.07	5.3	4.2 - 5.6	2.27 - 3.03
10 year Energy Consumption (kWh) (60 hr a week)	1,275,019	956,564	709,785	410,108
10 year CO2 (tonnes)	1,203	902	670	387
Energy Saving compare to T8		25%	44.33%	67.84%
Reduction of CO2 (tonnes) in 10 years		- 301	- 533	-816

Figure 18 Colour shift of some LED lighting products

The recommended best practices from Australia were similar to the view from Mr. Kasem Nincharoen from Thailand, who also presented some case studies on task-ambient lighting for office and data centers. However, he suggested that there seemed to be more barriers in trying convince building owners in Thailand due to the lack of accessible successful cases and also reasonable and good quality products in the local market. Stronger supports from government and high visibility demonstration projects are still needed.

For urban and landscape lighting, Mr. Satoshi Uchihara, a leading Japanese lighting consultant, presented the use of digitally controlled landscape and building façade lighting. His presentation however clearly demonstrated on the potential for reduced light pollution at night and enhanced energy efficiency opportunity with integrated lighting controls for landscape and facade lighting. His presentation demonstrated the opportunities associated with enhanced lighting experiences at night while obtaining significant energy savings in comparison to standard practices. His recommended best practice focused on enhance digitally controlled exterior and facade lighting, in line with the research and demonstration projects in the China; Thailand; and the United States.

For deep energy savings for industrial buildings, Prof. Steve Wong from Hong Kong, China gave a presentation on high performance LED high bay lighting with integrated advanced control systems. His presentation included a cross section of case studies illustrating the energy savings associated with high performance LED lighting in high bay applications, indicating greater than 50% savings. His best practice recommendation focused on converting conventional Metal halide and high intensity discharge lamps with digitally addressed LED fixtures and fully automated controlled using software for building energy management.

1.2.3 Discussions and Industry Input

During the end of the invited presentation sessions, we had the opportunity for formal input from a cross-section of industry and professional attendees/participants at the workshop. Here there was an open opportunity to input experiences, case studies and additional technologies to be included within the cross-section of best practices being developed at the workshop. Specific input included recommendations for lighting controls, daylighting for the tropics and high-efficiency LED lighting systems for the lighting of buildings.

There was also a general discussion on the importance of providing additional educational support, performance data and case studies to practitioners. There was strong input from the industry side at the workshop and there were multiple manufacturers who provided input support and commitment towards this evolving narrative on best practices. There was strong support specifically from Lutron and Phillips lighting on the importance of LED technology integrated with lighting controls. There was also general support from local lighting industry in Thailand on improved education of the lighting design community on advance controls and systems.

Initial list of lighting best practices

Best practices represented a broad cross-section of input from the APEC presentations as well as a series of ongoing discussions between members. Best practices were condensed into 16 separate elements representing a cross-section of input. A number of the individual best practices were joined together or summarized under a single best practice in order to condense the overall larger discussion/presentation. Effort was made to ensure that contributions were recognized from across the spectrum of participants in an inclusive manner. A condensed list of best practices based on the collective input from the first workshop is presented below.

1. **Adaptive lighting for exterior/public spaces-** this approach involves the use of advanced sensors and lighting fixtures to provide bi-level lighting for parking lots, pathways and other exterior lighting applications. In this approach the lighting response to vacancy and reduces to some lower level, upon detection of occupancy the lighting system would respond in return to full design levels. Savings of 40 to 50% have been routinely demonstrated in the number of case studies.

2. **Adaptive lighting for stair well/corridor lighting-** this best practice involves the application of sensors to reduce the light during periods of vacancy. Bi-level lighting in stairwells has been demonstrated to routinely save 40 to 50%. There are a number of commercially available products in the marketplace now implied in various parts of the APEC region as a best practice.

3. **Demand responsive lighting-** this approach involves reducing the light in an application by some small percentage during periods of heavy Power usage resulting in peak power savings. Evolving LED fixture systems with standard dimming drivers have the ability to easily integrate digital controls that can receive a remote signal to reduce light by some small percentage. This approach has the opportunity for significant benefit at a relatively small additional cost.

4. **Landscape lighting controls-** this best practice involves the use of advanced digital controls for façade and landscape lighting to provide additional design capabilities as well as greatly limiting the Time of use and potential wastage of lighting during off hours. Dynamic lighting Controls offer the potential for exciting and novel approaches for sod while minimizing the light pollution and waste.

5. **Simplified controls with User friendly interfaces-**overly complex lighting controls presents a significant barrier to the wide promulgation of this energy-saving approach. There is an evolving opportunity for simplified approaches for lighting controls that integrate user-friendly interfaces to achieve user satisfaction. User friendly interfaces will ensure that lighting controls are not disabled and the savings are actually achieved

6. **High bay lighting with advanced controls-** this best practice involves the use of high output high-performance LEDs in a conventional down lighting approach for high bay applications. There is a significant opportunity for savings from moving from traditional metal halide lights sources two LED in big-box and industrial high bay lighting.

7. **LED office lighting with motion/daylighting controls-** this best practice involves an integrated approach where LED lighting is coupled with Motion and daylight sensors to optimize savings as a bundled approach. Integrating these multiple Technologies introduces the opportunity for a significantly greater savings and cost-benefit. Savings of greater than 50% have been demonstrated.

8. **Smart LED street lighting-** this approach involves the integration of both LED and Digital Controls Ferdinand scheduling and dynamic dimming. There is a significant opportunity as we move from HPs lighting to LED lighting to incorporate an additional level of performance/ savings with the use of advanced lighting controls. Sample case studies in municipal application have demonstrated an enhanced capabilities and savings

9. **Daylighting harvesting in windowed spaces**- daylighting offers a significant opportunity for Energy saving in the operation of buildings however there is a significant need for the development of daylight harvesting and Trolls that are robust and reliable. Daylighting of buildings offers were the larger potentials for Energy savings but there is a critical need for more robust dynamic control hardware.

10. **Enhanced glare-free daylighting with shading-** daylighting can save significant amount of energy inside buildings however it also presents the opportunity for increased glare leading to occupant discomfort. The potential for discomfort prompts many occupants to use shading or drapes which then minimizes the amount of daily penetration into the space greatly limiting the opportunity for savings. Best practice solutions have been developed that greatly minimize the potential for occupant discomfort while offering the opportunity for daylight penetration deep inside space.

11. **Integrated Daylighting and task lighting with controls**- combining daylighting and task ambient lighting is a significant opportunity as a best practice design approach for buildings. In this case the daylighting provides the ambient component while electrical lighting provides optimized and personalized task lighting scenarios. This reduces the overall demand for daylighting and offers the opportunity for successful integration by minimizing the potential for glare.

12. **Task ambient lighting for offices-** this best practice involves the use of two different lighting approaches for providing office illumination, separating into an ambient and task component. In this approach the ambient fighting is significantly reduced from general practice in conjunction with high-performance task oriented lighting. This best practice has routinely demonstrated 40 to 50% savings and a number of case studies.

13. **LED dedicated/replacement lamps (residential/ commercial/industrial/retail)-** this best practice involves the use of LED lighting for both replacement and new design targeting incumbent light sources such as incandescent fluorescent and high intensity discharge**.**

14. **High reflectance surfaces for interiors-** this best practice involves the use of high reflectance ceiling surfaces to reduce the amount of light that is absorbed by the building surfaces. Typical ceiling reflectance is 80% and represents the vast majority of ceiling applications in APEC region (this means that essentially 20% of the light is lost by being absorbed into the ceiling material). High reflectance/high-performance ceiling materials have already been developed and representative a significant potential Best practice.

15. ***High efficiency sources, luminaires and control gear-*** as a best practice lighting design specifications should all involve the use of the highest efficiency sources, luminaires and control gear. For each one of these components there is an engineering efficiency either in lumens per watt, optical efficiency or efficiency factor for ballast/drivers. A best practice would move a specification from Standard efficiency to highest possible efficiency as commercially available for each component (best in class).

16. ***Building commissioning and operation (response to users)*** appropriate commissioning commissioning offers a significant opportunity for robust savings. This best practice involves the tuning/adjustment commissioning of building systems for lighting according to user preferences and desires. Additionally, as a best practice this would involve the application of user-friendly control systems that respond to user needs and desires overtime as a dynamic opportunity (as opposed to a one time commissioning effort at the time of occupancy).

With advanced lighting technologies, particularly with LED sources and digital/network lighting controls, there are potential savings by switching and/or controlling lighting systems at the beginning of installation and also during operation hours. The lighting systems can be programmed to respond to certain input such as occupancy/vacant sensors as opposed to providing constant target illuminance regardless of frequency of use or times of the day. As outlined above, demand-response lighting strategy can be applied in both indoor and outdoor applications and in commercial, residential as well as industrial buildings.

Complexity of the control technologies and high initial costs are among the main barriers. In addition, particularly for outdoor and public lighting applications, perceived safety and a lack of design and specification guidelines have an effect on building owners and facility managers' confidence. According to the discussion at the workshop, there were cases of automatic controls were disabled after the buildings were operated, thus, it was suggested that best practices should include simplified lighting controls with user-friendly interfaces as well as building commissioning to ensure that the controls are user responsive.

Focus and questions for break out groups. We identified five questions to help each breakout group developed the best practices. Each breakout group then took the group of best practices and develop them with the focus questions. The concept behind the focus questions was to help develop the educational program set up for the next workshop. Potential savings and scalability question was essentially to help potentially rank the best practices in terms of its suitability for inclusion. Questions relative to policy set and barriers are designed to help inform potential educational programs moving forward. Stakeholders and pathways are critical question hoping to inform the development work that will occur in Shanghai on the development of educational process. Questions for each best practice identified:

1. Potential savings
2. Scalability
3. Policy fit
4. Barriers
5. Educational pathways/ stakeholders

1.3 ASSESSMENT OF LIGHTING BEST PRACTICES

Based on the five key questions and outcomes reported from each one of the breakout groups, the followings describe five common themes of lighting best practices that would be included in the educational program. Each of the themes addressed barriers as well as potential target audiences for developing the education program.

1.3.1 Advanced Design and Lighting Specifications

1. **LED luminaires/replacement lamps (residential/ commercial/industrial/retail)**
   Policy fit-good policy fit
   Barriers- cost, performance data, lack of policy and incentives.
   Educational pathways/stakeholders-entire lighting network (designers/end-users/owners) government and regulatory.

2. **High efficiency sources, luminaires and control gear**
   Policy fit-good policy fit
   Barriers-added cost for components/industry focus on pay back approach, lack of codes and standardized performance data on performance, lack of incentives for increased cost
   Educational pathways/stakeholders-the entire lighting network (supplier- design)

3. **High reflectance surfaces for interiors**
   Policy fit-good policy fit
   Barriers- maintenance, lack of knowledge/experience, no case studies showing benefits and /or problems associated with using dark interiors
   Educational pathways/stakeholders-architectural/design community, Government/regulatory, facility owners/managers, Related industry

4. **Minimizing Light Pollutions**
Policy fit- good policy fit, similar to IDA dark sky ordinance
Barriers- public awareness, building and facility owners, architects, landscape designers
Educational pathways/stakeholders-municipalities, utilities, facility managers/owners, communities, lighting designers, landscape organizations.

These best practices are rather fundamental issues for building designers and engineers, yet there seemed to be knowledge gaps and lack of understanding on their importance and benefits on deep energy savings and lighting quality. While most economies have policies to promote and provide incentives for LED replacement lamps, there is a lack of understanding on advantages of using LED-dedicated luminaries together with lighting control systems as opposed to replacing the conventional lamps only. Also, using high efficacy light sources (high lumen output per 1 Watt) is only one factor contributing to saving lighting energy. The design community as well as government and regulatory should also address and promote the use of high performance luminaire (high output ratio) and related control gears.

For outdoor lighting, light pollution does not only waste energy, but can also create sky glow that affect the natural environment. Thus the architect, the landscape designer, and the lighting designer should be aware of specifying appropriate lighting techniques, types and installation methods of the luminaire for building facade, landscape and urban infrastructure. For example, flood lighting technique should be used with caution; the luminaire used should minimize the unwanted portion of lamp lumen direct upward to the sky. (Source:http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/lightpollution/indicatorDirectUplight.asp)

For indoor lighting, dark colour finishes (e.g. a dark grey wall reflects only 5-10% of the light) in the interior absorb most of the useful light, resulting in dim and gloomy interiors. Furthermore, the use of dark walls and ceilings in window-spaced could also cause discomfort glare due to excessive contrast of brightness between the window walls and the sky seen through windows. According to the on-going research by KMUTT and in-depth interviews with interior designers and lighting designers, these issues often undermine the energy saving intentions and also cause complains from building users.

1.3.2 Daylighting for the Tropics

1. **Enhanced glare-free daylighting with shading**
Policy fit- good policy fit
Barriers-cost, demonstrated solutions, knowledge and experience in the design community
Educational pathways/stakeholders-architectural/lighting design community, regulatory, building owners/operators, end-users facility managers, window and shading systems manufacturers.

2. **Daylighting harvesting in windowed spaces**
   Policy fit- good policy fit
   Barriers- knowledge, lack of proven approaches/ availability of controls systems, controls that work, appropriate commissioning of systems
   Educational pathways/stakeholders- regulatory community, design/architectural, controls manufacturers, contractors/installers, facility managers/building owners

3. **LED office lighting with motion/daylighting controls (smart office lighting)**
   Policy fit- good policy fit best for new construction
   Barriers-lack of knowledge/case studies, financial incentives, labeling of systems, reliable sensors, commissioning and tuning.
   Educational pathways/stakeholders- training/contractor community, designers/architects, manufacturers associations, controls manufacturers.

Although daylight in the tropics is available for most of working hours, there are a number of challenges and barriers to successful use of daylight in building interiors. Minimizing associated heat gain and sky glare due to direct sunlight and very bright sky (i.e. high luminance) are among the main issues. This is particular the case for commercial building in urban areas with deep plans and side-lighting, where effective fenestrations such as shading devices and high performance glazing are required. More advanced and innovative solutions include, for example, optical film to redirect daylight deeper and more uniform into the interiors without having to resort to overhangs. However, apart from relatively much higher initial costs, there are both technical and knowledge barriers among the decision-makers and design professionals.

The main target audiences are, therefore, architects and owners or their representatives such as the facility management team as they are involved during the conceptual design stage. Subsequently, the interior designer and lighting consultant are the main key stakeholders who specify the interior layouts, colour/finishings, and internal shading devices - all of which could have an influence on effective use of daylight. Daylight harvesting is a best practice that aims to make use of incoming daylight by supplementing the artificial lighting. This could be achieved by applying appropriate controls such as daylight sensors, bi-level switches and occupancy sensors combined.

1.3.3 Task-ambient Lighting Systems for Offices

1. **Task ambient lighting for offices**
   Policy fit-good policy fit
   Barriers- educational/knowledge, experience, cost and economics, no standardized solutions/products, codes and policy restrictions. Many standard solutions for general lighting exist
   Educational pathways/stakeholders-developers, facility managers, architectural/ interior/ lighting design community, regulatory organizations, lighting design standards organizations, lighting manufacturers (task lighting)

2. **Integrated Daylighting and task lighting with controls**
   Policy fit-good policy fit
   Barriers-demonstrated systems/case studies, lack of knowledge with design community
   Educational pathways/stakeholders- the industry and architectural/design community, specifically manufactures of task ambient lighting systems/ and daylighting controls.

Task-ambient lighting systems for office buildings can save up to 40-50% of the lighting energy use compared to the common practice of providing uniform lighting to satisfy task illuminance across the entire office. Overall it could help reducing peak electricity demand and, when used together with building lighting control systems, also offers an excellent opportunity as one of the *demand-respond strategies*. During peak hours, the ambient lighting can be dimmed down approximately 10-12% with out negatively affecting the lighting quality for task lights. However, currently the adoption of task-ambient lighting technique is more accepted in developed economies particularly in Australia and the United States. Tighter codes and better informed interior designers and lighting consultants appeared to be among the successful factors.

In Hong Kong, China and Malaysia, on the other hand, government buildings seemed to take a leadership role and then to establish design guideline for wider adoption by building professionals. For developing economies, more incentives and financial aids for both building owners and tenants are recommended. Nevertheless, knowledge and social barriers are common -in varying degree- among design professionals and key stakeholders in all economies.

According to an on-going research in Thailand by KMUTT, a social mechanism illustrates relationships among key stakeholders involved in the adoption of task-ambient lighting systems in office buildings. It was found that all the cases that used task-ambient lighting were LEED certified projects and most of them were newly built. Few successful cases, however, were the ones that could solve the associated discomfort from daylight (i.e. heat and glare) a lack of good quality task lights at reasonable price is also found to be one of the barriers. Thus, the education program should also address to the industrial designer as well as local lighting and office furniture suppliers so that suitable products can be developed.

1.3.4 Adaptive Lighting/ Demand-response Lighting

1. **Adaptive lighting for exterior and public spaces**
   Policy fit- leadership role followed by policy (leadership role in this case is an early adopter pre-code)
   Barriers-perceived safety, high cost, technological feasibly, confidence in working, outdated standard and codes
   Educational pathways/stakeholders-safety originations, municipalities, public/end users, architectural and lighting/specification community, building owners and operators. Large facility owners, Schools and universities public buildings.
2. **Smart LED street lighting (dark sky)**
   Policy fit- good policy fit-similar to dark sky IDA

Barriers- products and systems availability, lack of public awareness, cost/complexity.
Educational pathways/stakeholders- municipal/regulatory, design/specification community, street lighting manufactuers.

3. **Adaptive lighting for stair well/corridor lighting**
   Policy fit-leadership role followed by policy
   Barriers-outdated guidelines, codes and standards
   Educational pathways/stakeholders-building code/fire marshal, facility managers/owners, regulatory groups

4. **High bay lighting with advanced controls**
   Policy fit- good policy fit
   Barriers- product guidelines. design guidelines, performance data, case studies
   Educational pathways/stakeholders-building owners/managers, Esco, design community, Industrial-manufacturers associations/organizations

5. **Simplified controls with User friendly interfaces**
   Policy fit-good policy fit (simple switching approaches such as bi-level switches)
   Barriers-interoperability, rapid development of technology, complexity of control interface
   Educational pathways/stakeholders-interface designers, manufacturers, developers of building management systems, lighting designers/ architects/ specifier's

6. **Building commissioning and operation (user responsive controls)**
   Policy fit- good policy fit
   Barriers-poor design of control systems, variety of control systems, rapidly evolving market place
   Educational pathways/stakeholders-building operators, design community, suppliers/ manufacturers, regulatory community.

With advanced lighting technologies, particularly with LED sources and digital/network lighting controls, there are potential savings by switching and/or controlling lighting systems at the beginning of installation and also during operation hours. The lighting systems can be programmed to respond to certain input such as occupancy/vacant sensors as opposed to providing constant target illuminance regardless of frequency of use or times of the day. As outlined above, demand-response lighting strategy can be applied in both indoor and outdoor applications and in commercial, residential as well as industrial buildings. Complexity of the control technologies and high initial costs are among the main barriers. In addition, particularly for outdoor and public lighting, perceived safety and a lack of design and specification guidelines have an effect on building owners and facility managers' confidence. For interior lighting, there were cases of automatic controls were disabled after the buildings were operated, thus, it was suggested that best practices should include simplified lighting controls with user-friendly interfaces as well as building commissioning to ensure that the controls are user responsive.

1.4 SUMMARY

The results from the first workshop was particularly useful in identifying the links between policies on zero-net energy and/or deep energy savings, the lighting best practices, and on-going research and demonstration efforts. Some of these activities and applied research are collaborations between local government and university lighting research centers as well as professional institutions. Also there are some existing and new development of advanced facilities for research study which can be utilized for a more effective educational program for lighting best practices as suggested by this project - particularly, in the areas of daylighting in the tropics, task-ambient lighting systems and adaptive lighting controls. The experiences shared and lighting best practices proposed by the building professionals were also well in-lined with the ongoing policies and applied research carried out by the university lighting centers.

The presentations and discussions also highlighted some of the common technical, social and knowledge barriers to a wider adoption of lighting best practices. Though, to some extent, the knowledge barriers seemed to be greater in developing economies. Also the emphasis on advanced lighting controls appeared to be more explicit in the policies, building and lighting standards in the developed economies such as Australia and the United States, while in Thailand the emphasis was more towards the lamp and luminaire replacement with LED technology. The implementation of daylighting design and daylight harvesting in the economies with tropical climates - Indonesia; Malaysia; the Philippines; Singapore; and Thailand - seemed to share some critical technical and social barriers as well as knowledge gaps.

The summary discussion also focused on encouraging the academic community, the lighting researchers and the industry government policy stakeholders to work with the co-chairs on pulling together the educational program. The industry participants in the first workshop also reiterated their strong support for continuing the educational portion of the program. The workshop in Shanghai, China represented the second part of the overall plan on best practices with the objective of moving to supportive educational programs/pathways. The objective was to evolve effective educational programs that would assist in encouraging the broad adoption/ promulgation of best practices. The initial attributes were identified as follow:

- Potential Effectiveness at promulgating best practices
- Ability to be updated and modified overtime
- Collaborative and collective in nature
- Address multiple concerns and issues associated with data case studies recommendations

CHAPTER 2
DEVELOPING EDUCATION PROGRAM

The previous chapter described the procedure and results obtained from the information shared and discussions during the first workshop. Five main themes of lighting best practices were identified, along with barriers and potential target audiences for each of the sub-themes. This chapter covers the development of education pathways at the second workshop in Shanghai, where the experts collectively discussed and agreed on the overall goals and main attributes of the program. Subsequently the course structure and objectives were evolved; recommendations on equipments and activities for training were also provided.

2.1 THE SECOND WORKSHOP OVERVIEW AND PROCEDURE

Overview

The second APEC-funded lighting experts workshop held at Kingswell Tongji Hotel, on 15-16 September 2016 in Shanghai, China. This workshop was co-hosted by Tongji University, UC Davis and King Mongkut's University of Technology Thonburi. Seventeen people from seven APEC economies attended the workshop and 45% of them were female. They were from China; Hong Kong, China; Korea; Malaysia; Singapore; Thailand; and the United States.

Prior to the workshop, the organizing team sent via email a draft of workbook to the participants for review and preparation. Over the two-day workshop the invited experts reviewed the list of lighting best practices and agreed on potential educational pathways proposed from the first workshop in Bangkok. The break out groups were working on the structure and work flow for an effective educational program that would suit audiences in order to support the ZNE policies. There was also a discussion on how to formalize this collaboration and sustain the project.

Objectives

1. Review and agree upon a final list of lighting best practices and an effective educational pathway that can best reach the respective audiences involved with energy efficient lighting
2. Develop a structure of the curriculum, content lists and make recommendations on how it can be integrated with the existing training programs of building professionals in the APEC region
3. Establish working groups to follow up on its progress and contribute to the contents as well as to initiate future activities that could sustain the project

Workshop Structure

Prior to the workshop, the working team (KMUTT, Tongji and UC Davis) developed and distributed a work book to the lighting experts and participants to review and prepare to report at the workshop. The work book comprised 1) an overview of lighting best practices listed at the first workshop 2) possible educational pathways, stakeholders/audiences and attributes of effective pathway to focus on 3) working agenda and objectives the second workshop. The participants were also asked to consider which one of the three working groups they would like to join. These include the structure/contents, the work flow and the funding of the educational program. The work book was introduced at the beginning of the two-day workshop. Figure 19-21 shows the atmosphere during the discussions and presentation at the workshop in Shanghai.

Figure 19-21 Conducting workshop in Shanghai, China

At the beginning of the first day, the objectives of the project and the second workshop were also reviewed as some of the experts and participants were not at the first workshop in Bangkok. Subsequently all were invited to share their experiences and make suggestions on what proposed in the work book. The first half of the day was mainly to agree upon the final list of lighting best practices and identify the most effective educational pathway considering the attributes concluded from the first workshop as - rapid, inexpensive, expandable/flexible for updates and collective narrative. It was then agreed to focus on a webpage resource to deliver an educational program for building professionals in the APEC region.

In the second-half of the first day, the participants were divided into three working groups according to their choice and expertise. The first group worked on the structure and content of the educational webpage resource as well as the initial appearance of the page that would be suitable and appeal to the target audiences. These include architects and design community, electrical consultants, regulatory/policy makers, researcher/educator, lighting industry and also owners The second group focused on the work flow and coordination of the development; the last group worked on funding, partnership, and explore opportunities to connect it with existing professional educational activity and conferences.

2.2 FRAMEWORK OF THE EDUCATIONAL PATHWAY

There has been an agreement on the final list of lighting best practices to be included and also an overall objective and direction of this educational program. As reliable contents on lighting basics can be easily accessed from elsewhere such as IESNA and CIBSE, this webpage resource would focus on educating key stakeholders with advanced information on real cases and current research by university partners and lighting centers in the APEC region. This would provide a common platform for sharing and knowledge transfer from applied research as well as valuable case studies with proven deep energy savings. Also to maintain the impartial role of the resources, it was agreed that the page would be hosted by KMUTT, and maintained by the Lighting Research and Innovation Centre (LRIC). Its maintenance would be funded by small annual contributions from professional (non-profit) organizations in each economy partners.

Thus the webpage resource (www.lighting-bestpractices.org) comprised five main categories:

1. General information about the partnership and overall goal of this APEC region collaboration on providing educational resources for building professionals
2. News and Update on upcoming events and trainings, seminars and workshops
3. Lighting Best Practices overview: 1) Daylighting in the tropics 2) Adaptive Lighting/Advanced Controls 3) Advanced design and specifications 4) Task-ambient Lighting for Offices 5) Minimizing Light Pollution
4. Education resources for downloading - course outlines, presentations, guidebook, and case studies (in PDF)
5. Current research by partner institutions and its contribution to this education program

The overall goal was to provide a framework for educating and sharing with the lighting and building professionals as well as other key stakeholders, supported by updated current research and emerging technologies. We also believed that the case studies with successful results (or valuable lessons to be learned) and to build up confidence for practitioners and decision-makers would be very valuable, particular in the developing countries where there are few demonstration projects and successful cases. The executive members from participating economy would submit the new contents and case studies to a panel of reviewer before uploading on to the webpage. Finally there is an on-going discussion on possibility to connect this program to an existing training programs as well as to organize it as a parallel session to lighting conferences in the APEC region. Currently there are two possibilities as some the executive members are part of the organizing committee. The first one is the International Lighting Conference for Asia-Pacific (LUX Pacifica), which is organized once every four years and the next one is hosted by Japan on 6-8 March 2018. The second one, the Lighting Conference of China; Korea; and Japan (CJK Lighting Conference)[2], is in the process of evolving into the Asian Lighting Conference.

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[2]The Lighting Conference Co-operation Agreement was made 28 September 2010 between China Illuminating Engineering Society(CIES), Illuminating Engineering Institute of Japan (IEIJ) and Korean Institute of Illuminating and Electrical Installation Engineers(KIIEE).

2.3 EDUCATIONAL PROGRAM AND COURSE OUTLINE

According to the assessment of lighting best practices and critical barriers, the following educational program has been recommended. The program comprises eight courses, divided into three levels as shown in Table 3. According to the survey and discussions at the workshop, the university lighting research centers and professional organizations in most economies, e.g. The Thai Illuminating Engineering Association (TIEA) and Malaysia International Commission on Illumination (My CIE), have already provided training courses for lighting and building professionals. Thus this recommended program and courses are intended to provide a clearer path to reducing the barriers for adopting the identified lighting best practices.

Table 3 Recommended Courses for Lighting Best Practice

Program Level	Course Name
Fundamental	1.Lighting and Visual Perception
	2.Today's Lighting Technology
Intermediate	1.Understanding Light Pollution
	2.Task-Ambient Lighting Systems
	3.Daylighting for the Tropics
	4.Lighting Control Technology
Advanced	1.Innovative Daylighting for the Tropics
	2.Adaptive Lighting in Practice

A curriculum guidebook, which can be found in **Appendix II**, provides information about the overall goal of this educational program, course descriptions and topics to be covered as well as recommended tools and activities for each of these courses. The recommendations provided were based on the teaching and training experience of the lighting experts in the region. However, as basic knowledge of the target audience and available teaching facilities may vary in each economy, the delivery of the courses should be adjusted accordingly. In addition to the guidebook, other teaching materials such as slide presentations and case studies can be downloaded from the project website. Update information on training courses that are opened for professionals in the region can also be found in the 'News' section.

Figure 22-24 show the program and activities from the *Daylighting Design and Innovation* course offered by KMUTT during 6-13 December 2016 in Bangkok, Thailand and lead by Dr. Acharawan Chutarat. The course conducted in English and participants were architects, engineers and lighting consultants from Malaysia; the Philippines; and Thailand. Apart from lectures, the activities included hands-on experiment using the artificial sun to evaluate effective shading devices, and site visits to a LEED certified office of the Thai Health Foundation in central Bangkok. The participants also received trainings on daylight simulation softwares.

Figure 22 Course poster

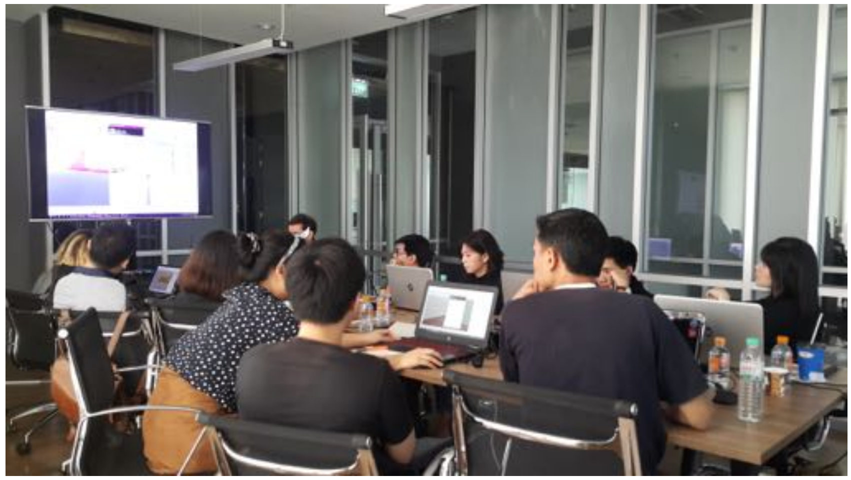


Figure 23 Daylighting software training

Figure 24 Experiments using the artificial sun

LIGHTING AND SEEING

PROGRAM LEVEL

Fundamental (3 contact-hours)

TARGET AUDIENCE

Architects, Interior Designers, Building consultants, Electrical Engineers, Facility Managers, Municipality/Utility

COURSE DESCRIPTION

Over the two training courses, this first part provides an understanding of how our visual systems response to the luminous environment and enable us to see in different brightness conditions (i.e. photopic, mesopic and scotopic vision). It introduces basic visual functions such as adaptation and accommodation, influencing how well we perform visual tasks and perceive comfort. It also explains the importance of human factors in lighting and process of visual perception for colour objects, brightness and discomfort/glare. These issues are essential to a better understanding of how the design, colour and texture of the built-environment, together with lighting systems, can contribute to a comfortable and pleasant visual environment, while help saving the energy.

LEARNING OBJECTIVES

1. Identify factors influencing the visual perception under different brightness levels (indoor and outdoor light levels)

2. Recognize visual requirements of users (young/aging) and different types of task e.g. reading/writing, using VDT screens, face-to-face communication

3. Identify design parameters and lighting requirements that are suitable for given applications, considering both energy efficiency and visual quality

4. Evaluate causes of visual discomfort/glare from both daylight and artificial lighting

EVALUATION OF LEARNING OBJECTIVES:

- Identify characteristics of lighting requirements for given visual tasks and applications
- Make suggestions how to improve quality of visual conditions, particularly brightness and glare perception (e.g. describe the importance of vertical brightness, simultaneous contrast)

TODAY'S LIGHTING TECHNOLOGY

PROGRAM LEVEL

Fundamental (3 contact-hours)

TARGET AUDIENCE

Architects, Interior Designers, Building consultants, Electrical Engineers, Facility Managers, Municipality/Utility

COURSE DESCRIPTION

Over the two training courses, this second part provided an overview of technical concepts and performance criteria of light sources, luminaire and its auxiliary equipments such as colour metrics (Correlated Colour Temperature-CCT and Colour Rendering Index-CRI) and photometric data of different types of luminaire. Light sources include conventional light sources as well as solid-state lighting (SSL). In particular, it introduces general considerations and selection criteria for Light-emitting Diodes (LED) replacement lamps and dedicated LED luminaire for retrofitting projects.

LEARNING OBJECTIVES

1. Identify common light sources and auxiliary equipment necessary for their operation

2. Evaluate correctly the quality and efficacy of a light source from the metrics provided on the label and/or manufacturers product literature

3. Recognize and articulate important aspects of color quality including the difference between CCT and CRI when shown an example or image

4. Determine if a light source and luminaire is suitable for given applications and compliant with local Building Energy Efficiency Standards and/or Appliance Efficiency Regulations

EVALUATION OF LEARNING OBJECTIVES:

- Select of suitable lamps and luminaire types for given applications and room geometry
- Identify the energy efficiency and colour quality criteria for common applications
- Compare advantages and disadvantaged of different light sources and luminaire types

MINIMIZING LIGHT POLLUTION

PROGRAM LEVEL

Intermediate (3 contact-hours)

PRE-REQUISITE

Lighting and Seeing; Today's Lighting Technology

TARGET AUDIENCE

Architects, Landscape designers, Lighting consultants, Electrical Engineers, Facility Managers, Manufacturers, Municipality/Utilities

COURSE DESCRIPTION

This course review the visual conditions during low light levels (mesopic and scotopic vision), then provides an overview of light pollution causes and effects on our environment. Particular interests are the provision of exterior lighting for building facade, landscape, pathways, parks, streets and other infrastructure in urban areas. It can be avoided or minimized by providing only necessary light lumens on the right surfaces, using the right luminaire and lighting equipment to control light trespass and reduce the energy use. The course introduces relevant design guidelines, describing different categories of exterior environment such as types of streets and frequency of use - to determine lighting design criteria, types of luminaire, lighting techniques that ensures safety, aesthetic and comfort.

LEARNING OBJECTIVES

1. Recognize the importance of minimizing light pollution by appropriate design and installation and maintenance

2. Evaluate potential causes of light pollution from existing installations against design criteria and suggest solutions to improve

3. Identify lighting requirements for a given application and site context and select appropriate lighting techniques and luminaire/equipments for a given application

EVALUATION OF LEARNING OBJECTIVES:

- Describe design parameters and lighting requirements for a given site context
- A project: Identify and select appropriate lighting techniques, luminaire and equipment, installation methods for a given application

TASK-AMBIENT LIGHTING FOR OFFICES

PROGRAM LEVEL

Intermediate (6 contact-hours)

PRE-REQUISITE

Lighting and Seeing

TARGET AUDIENCE

Interior Designers, Architects, Lighting Designers, Green Building/LEED consultants, Electrical engineers, Facility Managers, Municipality/Utilities, Lighting and Office Furniture Industry

COURSE DESCRIPTION

This course introduce benefits and principles of task-ambient lighting systems for offices that are not only energy-efficient, but can provide flexible and good quality lighting for today's working environment and multi-generation workforce. The participant will learn about different types of task-ambient lighting systems and how to integrate them successfully into the workplace interior and lighting design. The topics include the principles of task, ambient and vertical lighting as well as the lighting economics to justify the investment in new and retrofit projects.

LEARNING OBJECTIVES

1. Understand quality criteria of the luminous environment for today's workplace as well as the the future trend
2. Recognize design principles of task-ambient-vertical lighting systems and benefits on energy savings and lighting quality
3. Identify suitable task-ambient-vertical lighting systems for different visual requirements and types of project
4. Evaluate lighting economics of the task-ambient lighting systems and possible points that can be earned according to LEED or local green building schemes

EVALUATION OF LEARNING OBJECTIVES:

- Identify characteristics of effective task-ambient lighting systems for offices that can save at least 40% of lighting energy use compared to local building codes

- Group project: Develop and evaluate task-ambient (with vertical lighting) system for a given site and work environment

DAYLIGHTING IN THE TROPICS

PROGRAM LEVEL

Intermediate (6 contact-hours)

PRE-REQUISITE Lighting and Seeing

TARGET AUDIENCE

Architects, Interior Designers, Building consultants, Electrical Engineers, Facility Managers, Manufacturers (e.g. glazing and control)

COURSE DESCRIPTION

This course introduces the principles and design tools for daylighting design in the tropical climates. While daylight is a renewable energy and has other visual and psychological benefits, there are challenges to bring in diffuse daylight uniformly into the building interiors without causing thermal and visual discomfort to the building occupant. This course gives a holistic view of daylighting design, addressing human factors and design parameters. These include site context, orientations, fenestration design such as types of shadings, glazing properties and sizing as well as interior design that can have an effect on daylight availability and distribution inside the buildings.

LEARNING OBJECTIVES

1. Understand the characteristics of daylight (i.e. diffuse skylight) that are suitable for using inside the tropical building

2. Recognize building design parameters that can have an effect on the amount and quality of daylight in the interior

3. Evaluate effective shading devices that can prevent direct sunlight, while allowing useful and comfortable daylight to enter the interiors

4. Apply appropriate tools for evaluation of quantity and quality of daylight

EVALUATION OF LEARNING OBJECTIVES: WRITTEN EXAM AND A PROJECT

- Identify characteristics of fenestration design and glazing that are suitable for the tropics
- Group project: Develop and evaluate external/internal shading devices suitable for a given space and application

LIGHTING CONTROL TECHNOLOGIES

PROGRAM LEVEL

Intermediate (6 contact-hours)

PRE-REQUISITE

Today's Lighting Technology

TARGET AUDIENCE

Lighting Consultants, Green Building Consultants, Electrical Engineers, Facility Managers, Manufacturers (lighting control), Municipality/Utilities

COURSE DESCRIPTION

This two-part training course provides an overview of lighting control technologies and system interoperability, addressing limiting factors of emerging technologies with existing infrastructure. It also discuss human's perception of dimmed light levels which is not proportional to changes in input power. It introduces major dimming load types for different light sources including fluorescent, HID and particularly LED lighting. It explains LED dimming control signals - phase control, 0-10VDC, and control by digital signals (i.e. DALI) and selection criteria or advantages for using in new or retrofit projects. Finally it discusses characteristics of dimming control systems (wall box, multi-zone/multi-scene presets integrated).

LEARNING OBJECTIVES

1. Understand common communication protocols of lighting controls
2. Determine of a dimmer or other lighting control will function with a certain light source
3. Identify suitable lighting control system for a given space and functions

EVALUATION OF LEARNING OBJECTIVES: WRITTEN EXAM

- Describe characteristics of lighting controls suitable for certain light sources in new and retrofit projects
- Identify suitable dimming control systems for LED and propose lighting scenes for a given application / different functions

ADVANCED DAYLIGHTING IN THE TROPICS

PROGRAM LEVEL

Advanced (6 contact-hours)

PRE-REQUISITE

Daylighting in the Tropics

TARGET AUDIENCE

Architects, Lighting Consultants, Green Building Consultants, Electrical Engineers, Facility Managers, Manufacturers (e.g. glazing and control)

COURSE DESCRIPTION

This two-part training course provides advanced knowledge on innovative daylighting strategies in the tropical climates. These include passive strategies of light shelves, horizontal and vertical light pipes, other light guides such as optical films. In addition to the advanced daylighting strategies, successful daylight harvesting also depends on appropriate furniture layouts (e.g. orientations of computer screen), interior finishes, and types of internal shadings. An integrative approach with artificial lighting systems using photosensors and/or occupancy sensors is also essential for deep energy savings. The aim is to provide effective shadings to minimize direct sunlight and sky glare, while admitting more diffuse daylight deeper into the office interiors. The participants will learn how to validate and assess optimal daylighting design solutions that take into account thermal and visual comfort and energy efficiency.

LEARNING OBJECTIVES

1. Recognize characteristics of different innovative daylighting systems suitable for the tropics

2. Understand concept of the integration of daylight with electric lighting, using sensors and controls

3. Identify and evaluate effective daylighting performance suitable for a given site and space, taken into account both thermal and visual comfort

EVALUATION OF LEARNING OBJECTIVES: A DESIGN PROJECT

- Identify characteristics of exterior and interior design parameters as well as daylight controls
- Group project: Develop and evaluate innovative daylighting systems performance for a given space and application

ADAPTIVE LIGHTING

PROGRAM LEVEL

Advanced level (6 contact-hours)

PRE-REQUISITE

Lighting Control Technologies

TARGET AUDIENCE

Lighting Consultants, Green Building Consultants, Electrical Engineers, Facility Managers, Manufacturers (lighting control), Municipality/Utilities

COURSE DESCRIPTION

This two-part training course provides a holistic view of adaptive lighting, including its principles and benefits on energy savings. It also discuss potential effects that adaptive lighting may have on users' satisfaction and controllability as well as the visual perception of brightness and perceived safety, particularly for public lighting at night-time. It introduces current and future trends in lighting controls, particularly for energy management system, intelligent/ smart network i.e. an interconnected system of computers and devices control technologies. The participants will learn about types of network control protocol, communication typologies and advantages of wireless networked applications for new and retrofit projects. Finally, different types of sensors and occupancy parameters are introduced.

LEARNING OBJECTIVES

1. Recognize the benefits of advanced control systems that are responsive to the occupant's use

2. Understand differences in network control protocols and communication typologies

3. Identify suitable adaptive lighting strategies and control technology for a given application and context

4. Determine suitable type and occupancy parameters of sensors to be used in a given space

EVALUATION OF LEARNING OBJECTIVES:

- Describe benefits and considerations for adaptive lighting in major applications e.g. offices, streetlights, pathways

- Evaluate energy saving potentials from using different lighting control systems

APPENDIX I:

AGENDA OF THE WORKSHOPS

Asia-Pacific Economic Cooperation

King Mongkut's University of Technology Thonburi

Establishing lighting best practices and educational programs in support of zero net energy policy

An APEC regional collaboration with university lighting centers and research institutions

2-3 June 2016
Chatrium Hotel Riverside
Bangkok, Thailand

Agenda

Asia-Pacific Economic Cooperation

King Mongkut's University of Technology Thonburi

Meeting of Minds 2.1
Best practices workshops for zero net energy policy

A roundtable conference hosted by King Mongkut's University of Technology Thonburi (KMUTT), Tongji University and University of California at Davis

Purpose of the meeting:

This is the first of two workshops that will bring together key thought leaders within the lighting efficiency arena with the objective of identifying strategies and best practices in support of zero net energy policy.

Specific agenda items:

1. Identify key best practices involving policies and opportunities technologies or design approaches that can achieve deep energy saving in the lighting of buildings
2. Learn from effective collaboration models among stakeholders and strategies of the successful implementation of policies and projects
3. Make recommendations on unified lighting best practices that can be applied to the design and retrofitting of buildings in the APEC region

Driving Forces:

Lighting consumes about 25% of world energy use, but can consume up to 33% of the energy used in developing economies. Due to pressing climate goals, many APEC economies are currently struggling to develop zero net energy (ZNE) roadmaps that rely heavily on achieving deep energy saving in an aging building stock. Retrofitting the existing building stock with highly efficient lighting is one of the most effective ways to achieve deep energy savings and rapidly reduce our dependence on fossil fuels.

Buildings' energy consumption constitutes one of the largest contributions to greenhouse gas emissions and has been targeted by many APEC economies as a priority opportunity, but there exists a considerable lack of knowledge on how to best achieve these "deep" energy saving and which strategies and practices should be employed with finite public investment. Unifying lighting best practices, and supporting educational curriculum has the potential to significantly increase the rate at which advanced lighting solutions are adopted across in developing member economies, decreasing the overall energy use.

Two sequential workshops are proposed to produce first a compilation of best practices for achieving deep lighting energy savings for both retrofit and new design of buildings. The second of the sequential workshops will result in an educational program and supporting curriculum that will be linked with the collaborating universities and lighting centers for the promulgation of the best practices.

The capacity building that will result from these two sequential workshops will enable developing APEC member economies to take full advantage of evolving best practices for effective lighting that will then be promulgated through an integrated educational infrastructure within the aligned economies. This synergistic activity of linking both the knowledge base and the educational infrastructure is a significant addition to capacity building within the APEC member economies.

Format and organization:

The roundtable meeting of experts will focus on the two specific components of the two-day program:

1) Lighting best practices implemented successfully and resulted in deep energy savings

2) Discussions and recommendations on unified best practices for buildings in the region

The 'Meeting of Minds 2.1' roundtable will be organized around a series of presentations from each invited expert, addressing these two components. We are asking that the invited experts talk about their specific experience in energy-efficient lighting policies, advanced research and design strategies in real projects.

In addition to presentations by the experts, we will present initial results from pre-workshop surveys on current best practices and some educational programs in the region. This is to provide a background information for our discussions which will take place on the second day of the workshop. The concept is to share experiences and opportunities to achieve sustainable lighting design. Specific focus will be placed on identifying lighting best practices and effective strategies to transfer the knowledge through educational programs for building professionals.

Key questions relative to establishing unified lighting best practices:

- What are the lighting design strategies that can lead to deep energy savings?
- What are energy-efficient lighting policies that are effective?
- What major activities required to implement these policies?
- What models of collaborations among stakeholders are effective?
- How lighting and building professionals can contribute to these processes?
- How lighting industry can engage in promoting these best practices?
- What are opportunities for developing educational programs on energy-efficient lighting for building professionals?

Meeting Agenda

Workshop to Establishing Lighting Best Practices Educational Programs to Achieve Deep Energy Saving

Date : **Wednesday, 1 June 2016**
Venue: **Chatrium Hotel Riverside (The Silver Waves, 36th floor)**
Time: **6:00 PM - 8:30 PM**
Event: Welcome dinner (hosted by KMUTT)

Time	Event
6:00 PM	Welcome drink at **The Silver Waves** Restaurant, 36th Floor
6:30 PM	Thai set dinner
20:30 PM	Closing

Meeting Agenda

Workshop to Establishing Lighting Best Practices Educational Programs to Achieve Deep Energy Saving

Date : **Thursday, 2 June 2016**
Venue: **The River Room, Chatrium Hotel Riverside, Bangkok, Thailand**
Time: **8:30 AM - 16:30 PM**
Event: Meeting Day 1

Time	Event	Presenter
8:30 AM	Registration	All
9:00 AM	Welcome speech by Assoc. Prof. Sakarindr Bhumiratana	KMUTT President
9:10 AM	Keynote speaker: Energy-efficiency policies and strategies in Thailand	EPPO, Ministry of Energy
9:30 AM	Introduction and overview of the workshops and presentations	Asst. Prof. C. Chuntamara
9:40 AM	From lighting design research to best practices in California by CLTC	Prof. Michael Siminovitch
10::20 AM	Coffee break	
	Presentations (lighting best practices)	
10:40 AM	Effective lighting innovation demonstrations and outreach programs by	Mr. Alan Suleiman
11:00 AM	Roles of lighting design guidelines and education programs in Australia	Prof. Warren Julian
11:20 AM	Energy-efficient lighting policies and best practices in Hong Kong	Prof. Steve Wong
11:40 AM	Energy-efficient lighting technology research and case studies in Singapore	Prof.Tseng and Dr. Chien
12:15 AM	Lunch break	
	Presentations (lighting best practices)	
13:45 PM	Lighting best practices and demonstration facilities in Beijing, China	Dr. Rong Haolei
14:05 PM	Lighting innovation and applications of LED in China, Japan and Korea	Prof. Nianyu Zou
14:25 PM	Advanced LED technologies and best practices for office buildings -	Ms. Ying Ching Hui
14:45 PM	Energy-efficient lighting policies and strategies in Indonesia	Mr. Hermann Endro
15:00 PM	Coffee break	
	Presentations (lighting best practices)	
15:20 PM	Implementations of lighting best practices in Indonesia	Mr. Totok Sulistiyanto
15:40 PM	Application of innovative daylighting in high-rise buildings - Malaysia	Mr. Gregers Reimann
16:00 PM	A novel glare assessment tool for daylighting in the tropics - Malaysia	Dr. Michael Hirning
16:15 PM	Discussions and summary of the presentations	Prof. Michael Siminovitch
16:30 PM	Closing for Day 1	All

Meeting Agenda

Workshop to Establishing Lighting Best Practices Educational Programs to Achieve Deep Energy Saving

Date : **Friday, 3 June 2016**

Venue: **The River Room, Chatrium Hotel Riverside, Bangkok, Thailand**

Time: **8:30 AM - 16:30 PM**

Event: Meeting Day 2 & Thank you dinner

Time	Event	Presenter
8:30 AM	Registration	All
9:00 AM	Keynote Speaker: Strategies to promote energy-efficient lighting by EGAT	DSM Director, EGAT
9:20 AM	Energy-efficient lighting policies and strategies by BCA in Singapore	Mr. Jeffery Neng
9:40 AM	Lighting policies and the adoption of advanced LED technologies in Japan	Mr. Satoshi Uchihara
10::00 AM	Coffee break	
	Input from stakeholders	
10:20 AM	Lighting design research and opportunities for ZNE in Thailand	Asst. Prof. C.
10:35 AM	Roles of building professionals on energy-efficient lighting in Thailand	Mr. Kasem Nincharoen
10:50 AM	Advanced lighting technologies and roles of lighting industry in the region	Moderated by Dr. A. Chutarat
11:30 AM	*Discussions* on collaboration models among stakeholders	All
12:00 AM	Lunch break	
	Small group discussions	
13:30 PM	Review of lighting best practices on effective policies and lighting	Prof. Luoxi Hao
13:40 PM	Small group discussions	All
14:40 PM	Coffee break	
	Presentations and unified best practices	
15:00 PM	Presentations of each group	Moderators/ Group
15:40 PM	Agreement on saving opportunities, policies & educational pathways	Prof. Michael Siminovitch
16:00 PM	Workshop summary by Dr. Chuntamara and closing remarks by Prof. Luoxi Hao	
	Thank you dinner	
18:00 PM	Meeting at Chatrium Pier and depart for SALA Rattanakosin restaurant	
21:00 PM	Depart from the restaurant back to Chatrium	

Meeting venue:

The River Room, Chatrium Hotel Riverside

Charoen-krung Road, Bangkok

Establishing Educational Pathways for Lighting Best Practices

An APEC regional collaboration with university lighting centers and research institutions

15-16 September 2016
Kingswell Hotel Tongji
Shanghai, China

Agenda

Asia-Pacific
Economic Cooperation

Meeting of Minds 2.2
Educational Pathways for Lighting Best Practices

A roundtable conference co-chaired by Tongji University

Purpose of the meeting:

This is the second of two workshops that will bring together leading lighting researchers and educators as well as experts within the lighting efficiency arena with the objective of identifying educational pathways for best practices in the Asia-Pacific region.

Specific agenda items:

1. Identify educational pathways for disseminating knowledge on new technologies and design approaches that can achieve deep energy saving in the lighting of buildings
2. Establish strategies and communication mechanism that can best inform stakeholders and transform the marketplace
3. Develop structure and key components of the key educational pathway (website) that can be applied to the design and retrofitting of buildings in the APEC region

Driving Forces:

Lighting consumes about 25% of world energy use, but can consume up to 33% of the energy used in developing economies. Due to pressing climate goals, many APEC economies are currently struggling to develop zero net energy (ZNE) roadmaps that rely heavily on achieving deep energy saving in an aging building stock. Retrofitting the existing building stock with highly efficient lighting is one of the most effective ways to achieve deep energy savings and rapidly reduce our dependence on fossil fuels.

Buildings' energy consumption constitutes one of the largest contributions to greenhouse gas emissions and has been targeted by many APEC economies as a priority opportunity, but there exists a considerable lack of knowledge on how to best achieve these "deep" energy saving and which strategies and practices should be employed with finite public investment. Unifying lighting best practices, and supporting educational curriculum has the potential to significantly increase the rate at which advanced lighting solutions are adopted across in developing member economies, decreasing the overall energy use.

Recommendations from the First Workshop:

Two sequential workshops are proposed in Bangkok and Shanghai respectively. The first workshop, chaired by *Lighting Research and Innovation Centre - KMUTT,* was held on 2-3 June 2016 in Bangkok. It was organized around a series of presentations of best practices for achieving deep lighting energy savings for both retrofit and new design of buildings. Three broad groups of best practices were identified: 1) adaptive lighting/ demand-response lighting 2) daylighting harvesting & integration with task-ambient light 3) LED application with user-friendly and effective controls.

These were used as a basis for the roundtable discussions, which helped identifying the educational stakeholders and critical barriers many of which involved knowledge or experience gaps in the lighting field. Recommendations have been made on possible education pathways and initial structure of a common learning platform. The industry participants also reiterated their strong support for continuing the educational portion of the program. These results contributed to the organization of the second workshop in Shanghai.

Format and organization:

Objectives of the upcoming workshop is to evolve effective educational programs that will assist in encouraging the broad adoption of best practices among the design and building professionals as well as to identify funding mechanism and activities that will help sustaining the program. The roundtable meeting of experts will focus on the two specific components of the two-day program:

1) Discussions on effective educational pathways for lighting best practices
2) Recommendations on structure of the contents and how to inform stakeholders

The 'Meeting of Minds 2.2' workshop will be organized as a roundtable discussion of the invited experts as well as representatives from lighting industry addressing these two components. A draft workbook, outlining the structure of the workshop and issues to be discussed, is shared with each of the invited experts. In addition, we will present a list of lighting best practices and recommendations obtained from the first workshop in Bangkok. This is to provide a background information and to facilitate the sharing of experiences by each expert.

Key questions relative to establishing educational pathways for best practices:

- What are the most effective educational pathways for the APEC region?
- What are the key attributes and structure of the selected pathway?
- How to inform stakeholders and to collaborate with them in a long term?
- How lighting industry and building professionals can contribute to the programs?
- What should be funding mechanism and activities that can help promoting and sustaining the programs?

Meeting Agenda

Workshop to Establishing Lighting Best Practices Educational Programs to Achieve Deep Energy Saving

Date : **Thursday, 15 September 2016**
Venue: **Kingswell Hotel, Shanghai**
Time: **9:00 AM - 16:30 PM**
Event: **Meeting Day 1**

Time	Event	Presenter
9:00 AM	Welcome and opening remark	Prof. Luoxi Hao
9:15 AM	Introduction and organization of the workshop	Prof. Michael Siminovitch
9:30 AM	Lighting best practices and recommendations from the Bangkok workshop	Asst. Prof. C. Chuntamara
10:00 AM	Overview of education pathways for lighting best practices in the US	Prof. Michael Siminovitch
10::20 AM	Coffee break	
	Discussions: Education Pathways	
10:40 AM	Identifying effective education pathways and key attributes for the APEC region A focus on web-based platform	All
12:00 AM	Lunch break	
	Group Discussions: sub-committee	
13:30PM	Brainstorming and discussions in small groups: + Design and Contents + Hosting/management /work flow + Industry inks and funding opportunity/continuity	All/ small groups
16:00PM	Summary and Closing for Day 1	Prof. Luoxi Hao

Meeting Agenda

Workshop to Establishing Lighting Best Practices Educational Programs to Achieve Deep Energy Saving

Date : **Friday, 16 September 2016**

Venue: **Kings Well Hotel, Shanghai**

Time: **9:00 AM - 16:30 PM**

Event: **Meeting Day 2**

Time	Event	Presenter
	Report from sub-committee 1	
9:00 AM	Head of each sub-committee to report the results from group discussions/ Design and contents (design strategies, best practices, case studies)	Sub-Committee
10::20 AM	Coffee break	
	Report from sub-committee 2	
10:40 AM	Head of each sub-committee to report the results from group discussions/ Hosting/management /work flow and; Industry inks and funding opportunity/continuity	Sub-Committee
12:00 AM	Lunch break	
	Suggestions and Recommendations	
13:30PM	Suggestions and recommendations on the results proposed by each group	All
15:00 PM	Coffee break	
15:20 AM	Recommendations and agreement on tasks for each sub-committee	All
16:00 PM	Summary and Closing	Prof. Luoxi Hao

Conference Venue:
Kingswell Hotel Tongji
Yang Qu, Shanghai Shi, China 200092

Dinner hosted by Tongji University on 15 September 2016
Time and Venue is to be confirmed at the conference

APPENDIX II:

CURRICULUM GUIDEBOOK

Lighting and Visual Perception

Educational Program for Lighting Best Practices:
An APEC regional collaboration with university lighting centers and research institutions

Program Level
Fundamental

Pre-requisite
None

Best Practices
All

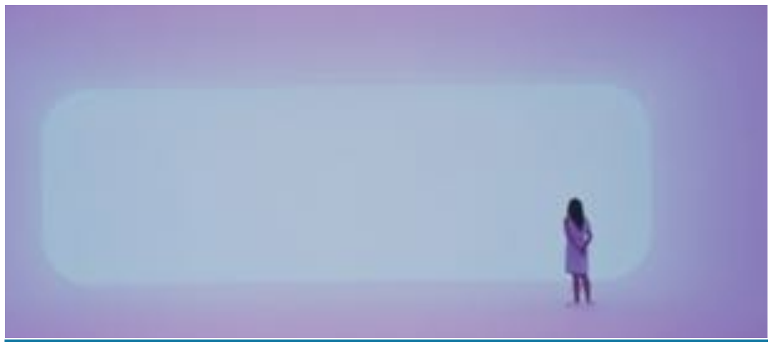


Figure 1 | Adaptation is one of visual mechanism

Course Outline

This is a two-part training course provides a fundamental understanding of how our visual systems response to the luminous environment and enable us to see in different brightness conditions (i.e. photopic, mesopic and scotopic vision). It introduces basic visual functions such as adaptation (Figure 1) and accommodation, influencing how well we perform visual tasks and perceive comfort. It also explains the importance of human factors in lighting and process of visual perception for colour objects, brightness and discomfort/glare.

These issues are essential to a better understanding of how the design, colour and texture of the interior and architecture, together with lighting systems, can contribute to a comfortable and pleasant visual environment, while help saving the energy. The course is delivered by lecture and demonstrations of how we perceive brightness and colour.

Learning Objectives:

- Identify factors influencing the visual perception under different brightness levels (indoor and outdoor light levels)
- Recognize visual requirements of users (young/aging) and different types of task e.g. reading/writing, using VDT screens, face-to-face communication
- Identify design parameters and lighting requirements that are suitable for given applications, considering both energy efficiency and visual quality
- Evaluate causes of visual discomfort/glare from both daylight and artificial lighting

Evaluation of Learning Objectives:

- Identify characteristics of lighting requirements for given visual tasks and applications
- Make suggestions how to improve quality of visual conditions, particularly brightness and glare perception (e.g. describe the importance of vertical brightness, simultaneous contrast)

Keywords
Visual systems, Human Factors, Visual perception, Glare, Colour perception

Education resources:
www.ligitng-bestpractices.org

Table 1 Teaching Equipment

Illuminance/Chroma meter Minolta T-10	Photo Spectrometer - Light passport	Luminance Colour meter Minolta CS-100A
		

Figure 2 | Demonstration of visual perception under different lights

Teaching Methods to be Used:

Individual Speaker

Slide presentation / Other visual aids

Group Participation / Hands-on experiment

Light measurements under daylight and artificial light at night time

Recommended Activities

- Measure illuminance levels (i.e. amount of light falling on a surface) in different settings, both bright and dark environment; explain the differences in photopic, mesopic and scotopic vision
- View and compare the same colour objects under daylight compared to different light sources
- With a full-scaled mock ups or scaled models of at least 1:10, demonstrate the effect of using dark VS light surfaces (for example, a black room with 10% reflectance compared to a white room with 80% reflectance) on the light levels at the same positions in the room.
- Demonstrate the effects of light at different brightness onto large surfaces in the space, particularly the vertical surfaces i.e. walls (Figure 2) - using the luminance meter to measure the reflected light in the participant's viewing direction.

Today's Lighting Technology

Educational Program for Lighting Best Practices:
An APEC regional collaboration with university lighting centers and research institutions

Program Level
Fundamental

Pre-requisite
None

Best Practices
All

Figure 1 | Luminaire with high performance optics and reflector (by Siteco)

Course Outline

Over the two training courses, this second part provided an overview of technical concepts and performance criteria of light sources, luminaire and its auxiliary equipments such as colour metrics (Correlated Colour Temperature and Colour Rendering Index-CRI) and photometric data of different types of luminaire with Ingress Protection (IP) ratings. Light sources include conventional light sources as well as solid-state lighting (SSL).

This course also introduces general considerations and selection criteria for Light-emitting Diodes (LED) replacement lamps and dedicated LED luminaire for retrofitting projects. The course is delivered through lecture and hands-on experiments as well as demonstrations of lighting effects from different types of luminaire for both exterior and interior applications.

Learning Objectives:

- Identify common light sources and auxiliary equipment necessary for their operation
- Evaluate correctly the quality and efficacy of a light source from the metrics provided on the label and/or manufacturers product literature
- Recognize and articulate important aspects of color quality including the difference between CCT and CRI when shown an example or image
- Determine if a light source and luminaire is suitable for given applications and compliant with local Building Energy Efficiency Standards and/or Appliance Efficiency Regulations. Figure 1 and 2 show high quality luminaire and a photometry laboratory.

Evaluation of Learning Objectives:

- Select of suitable lamps and luminaire types for given applications and room geometry
- Identify the energy efficiency and colour quality criteria for common applications
- Compare advantages and disadvantaged of different light sources and luminaire types

Keywords
Light sources, Luminaire, Colour metrics, Efficiency, Units of light

Education resources:
www.ligitng-bestpractices.org

Table 1 Teaching Equipment

Illuminance/Chroma meter Minolta T-10	Photo Spectrometer - Light passport	Luminance Colour meter Minolta CS-100A
		

Figure 2 I Testing of a light source in a photometry laboratory

Teaching Methods to be Used:

Individual Speaker

Slide presentation / Other visual aids

Group Participation / Hands-on experiments with light sources and luminaire

Site visit to see a testing laboratory

Recommended Activities

- Show different type of light sources and their packages or material from lamp suppliers and describe lamp selection criteria such as lamp efficacy and colour metrics
- Measurements of spectral power density (SPD) curves of different light sources - to show correlated colour temperature (CCT) and colour rendering index (CRI) of different type of light sources, particularly differences between incandescent, gas-discharged (e.g. fluorescents) and LEDs with low and high CRI (Figure 3).
- Visit a certified photometry laboratory with luminaire goniometer, so the participants understand the concept of photometric measurements or light distributions (Figure 4).

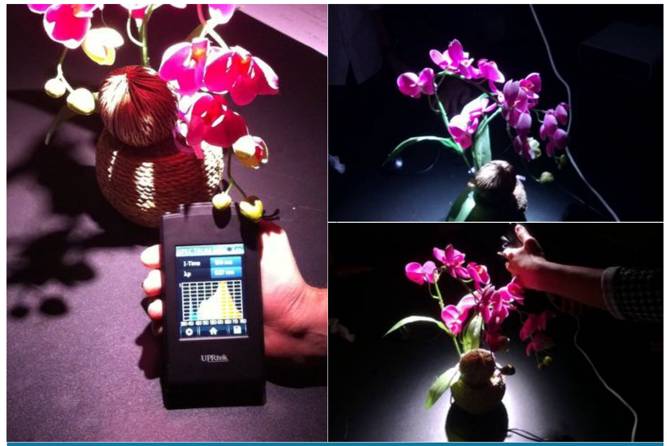


Figure 3 I Experiments with light sources with different CRI

Figure 4 I Lighting distributions from different luminaire types

Task-ambient Lighting Systems

Educational Program for Lighting Best Practices:
An APEC regional collaboration with university lighting centers and research institutions

Program Level
Intermediate

Pre-requisite
Lighting and Seeing

Best Practices
Task-ambient Lighting for Offices

Figure 1 | Task-ambient Lighting systems in real buildings

Course Outline

This course is recommended for interior designers, architects, lighting designers, green building/LEED consultants, electrical engineers, facility managers, municipality/utilities, lighting and office furniture industry. This course introduces benefits and principles of task-ambient lighting systems for offices that are not only energy-efficient, but can provide flexible and good quality lighting for today's workplace and multi-generation workforce.

The participant will learn about different types of task-ambient lighting systems and how to integrate them successfully into the workplace interior and lighting design (Figure 1). The topics include the principles of task, ambient and vertical lighting as well as the lighting economics to justify the investment in new and retrofit projects. The course is delivered through lecture, demonstrations with different types of task lights and a site visit.

Learning Objectives:

- Understand quality criteria of the luminous environment for today's workplace as well as the the future trend
- Recognize design principles of task-ambient-vertical lighting systems and benefits on energy savings and lighting quality
- Identify suitable task-ambient-vertical lighting systems for different visual requirements and types of project
- Evaluate lighting economics of the task-ambient lighting systems and possible points that can be earned according to LEED or local green building schemes

Evaluation of Learning Objectives:

- Identify characteristics of effective task-ambient lighting systems for offices that can save at least 40% of lighting energy use compared to local building codes
- Group project: Develop and evaluate task-ambient (with vertical lighting) system for a given site and work environment

Keywords
Task-ambient Lighting, Vertical illuminance, Visual comfort, Personal control

Education resources:
www.ligitng-bestpractices.org

Table 1 Teaching Equipment

Illuminance/Chroma meter Minolta T-10	Luminance Colour meter Minolta CS-100A	Different types of task lights
		

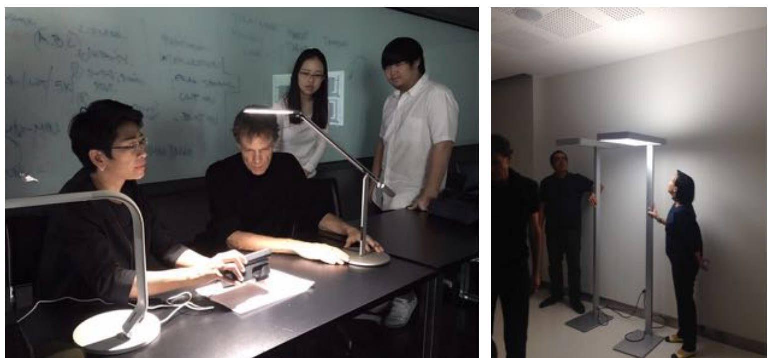


Figure 2 | Demonstration of different types of task lights

Teaching Methods to be Used:

Individual Speaker

Slide presentation / Other visual aids

Group Participation / Hands-on experiment

Light measurements under daylight and artificial light at night time

Recommended Activities

- Usability testing (control interface) of different types of task lights and measure illuminance and lighting distributions across the work areas (e.g. screens, paper, tablets)
- Evaluate the lighting and visual quality of the integration of reduce ambient light, added vertical lighting and task lights, using a full-scaled mock up facility (Figure 2)
- Visit to the a real project that successfully use task-ambient lighting to gain first-hand experiences and, if possible, interview the building occupant

Understanding Light Pollutions

Educational Program for Lighting Best Practices:
An APEC regional collaboration with university lighting centers and research institutions

Program Level
Intermediate

Pre-requisite
Fundamental Courses

Best Practices
Minimizing Light Pollutions

Figure 1 | Appropriate lighting techniques for exterior lighting

Course Outline

This course review the visual conditions during low light levels (mesopic and scotopic vision), then provides an overview of light pollution causes and effects on our environment. Particular interests are the provision of exterior lighting for building facade, landscape, pathways, parks, streets and other infrastructure in urban areas. It can be avoided or minimized by providing only necessary light lumens on the right surfaces, using the right luminaire and lighting equipment to control light trespass and reduce the energy use.

The course introduces relevant design guidelines, describing different categories of exterior environment such as types of streets and frequency of use - to determine lighting design criteria, types of luminaire, lighting techniques that ensures safety, aesthetic and comfort.

Learning Objectives:

- Recognize the importance of minimizing light pollution by appropriate design and installation and maintenance
- Evaluate potential causes of light pollution from existing installations against design criteria and suggest solutions to improve
- Identify lighting requirements for a given application and site context and select appropriate lighting techniques and luminaire/equipments for a given application

Evaluation of Learning Objectives:

- Describe design parameters and lighting requirements for an exterior lighting context
- A project: Identify and select appropriate lighting techniques, luminaire and equipment, installation methods for a given application that can achieve the visual requirements and minimize lighting pollution

Keywords
Exterior Lighting, Facade Lighting, Light Pollution, Landscape Lighting

Education resources:
www.ligitng-bestpractices.org

Table 1 Teaching Equipment

Illuminance/Chroma meter Minolta T-10	Luminance Colour meter Minolta CS-100A	Exterior luminaire with different photometric
		

Figure 2 | Luminaire creating light pollution

Figure 3 | Experimenting with different luminaire

Teaching Methods to be Used:

Individual Speaker / Panels

Slide presentation / Other visual aids

Group Participation / Hands-on experiment with different luminaire types

Light measurements at night time

Recommended Activities

- Workshop to demonstrate different types of exterior luminaire (e.g. narrow beam, flood-light, uplight, wall-washer), illuminating the same wall; then characteristics of the wall can change using different colors and materials. The participants can learn how this affect lighting effects, spacing and energy use.

- Visit sites with different lighting installations and evaluate against suitable guidelines whether there are wasteful lighting and/or use of inappropriate luminaire categories.

- An assignment to identify design criteria for a given application and specify appropriate lighting technique/installation methods and luminaire to achieve desired effects with minimum energy.

Lighting Control Technology

Educational Program for Lighting Best Practices:
An APEC regional collaboration with university lighting centers and research institutions

Program Level
Intermediate

Pre-requisite
Today's Lighting Technology

Best Practices
Adaptive / Smart Lighting

Figure 1 | Installation of adaptive lighting by California Lighting Technology Center

Course Outline

This two-part training course is recommended for lighting consultants, green building consultants, electrical engineers, facility managers, manufacturers (lighting control), municipality and utilities. This first part provides an overview of lighting control technologies and system interoperability, addressing limiting factors of emerging technologies with existing infrastructure. It also discuss human's perception of dimmed light levels which is not proportional to changes in input power.

It introduces major dimming load types for different light sources including fluorescent, HID and particularly LED lighting. It explains LED dimming control signals - phase control, 0-10VDC, and control by digital signals (i.e. DALI) and selection criteria or advantages for using in new or retrofit projects. Finally it discusses characteristics of dimming control systems (wall box, multi-zone/multi-scene presets integrated).

Learning Objectives:

- Understand common communication protocols of lighting controls
- Determine of a dimmer or other lighting control will function with a certain light source
- Identify suitable lighting control system for a given space and functions

Evaluation of Learning Objectives:

- Describe characteristics of lighting controls suitable for certain light sources in new and retrofit projects
- Identify suitable dimming control systems for LED and propose lighting scenes for a given application / different functions

Keywords
Lighting controls, Communication protocol, User interface, Adaptive lighting

Education resources:
www.ligitng-bestpractices.org

Table 1 Teaching Equipment

Wall dimmer switch	DALI control	Multi-zone, Multi-scene presets, integrated
		

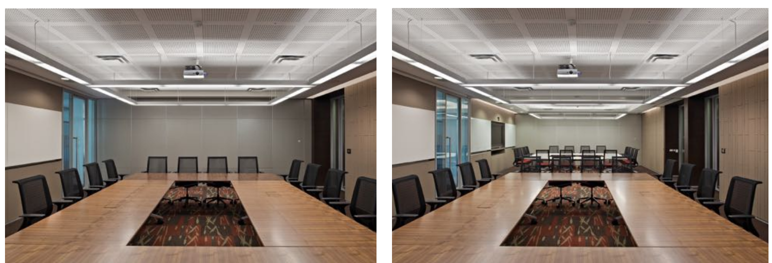


Figure 2 | Demonstration of lighting controls and scene setting

Teaching Methods to be Used:

Individual Speaker

Slide presentation / Other visual aids

Group discussion on appropriate use of lighting controls

Demonstration of lighting control - scene setting

Recommended Activities

- Demonstrate light sources and control system compatibility for major types - fluorescent and LED lighting
- Experiment the relationship between brightness perception and reduced light output
- Demonstration how to use and program lighting scenes (Figure 2)

Adaptive Lighting in Practice

Educational Program for Lighting Best Practices:
An APEC regional collaboration with university lighting centers and research institutions

Program Level
Advanced level

Pre-requisite
Lighting Control Technology

Best Practices
Adaptive / Smart Lighting

Figure 1 | Installation of PV smart lighting by California Lighting Technology Center

Course Outline

This two-part training course is recommended for lighting consultants, green building consultants, electrical engineers, facility managers, manufacturers (lighting control), municipality and utilities. This second part of the course provides a holistic view of adaptive lighting, including its principles and benefits on energy savings. It also discuss potential effects that adaptive lighting may have on users' satisfaction and controllability as well as the visual perception of brightness and perceived safety, particularly for public lighting.

This course introduces current and future trends in lighting controls, particularly for energy management system, intelligent/ smart network i.e. an interconnected system of computers and devices control technologies. The participants will learn about types of network control protocol, communication typologies and advantages of wireless networked applications for new and retrofit projects. Finally, different types of sensors and occupancy parameters are introduced.

Learning Objectives:

- Recognize the benefits of advanced control systems that are responsive to the occupant
- Understand differences in network control protocols and communication typologies
- Identify suitable adaptive lighting strategies and control technology for a given application and context
- Determine suitable type and occupancy parameters of sensors to be used in a given space

Evaluation of Learning Objectives:

- Describe benefits and considerations for adaptive lighting in major applications e.g. offices, streetlights, pathways
- Evaluate energy saving potentials from using different lighting control systems

Keywords
Adaptive lighting, Smart lighting, Advanced controls, Networked Control, Perceived safety

Education resources:
www.ligitng-bestpractices.org

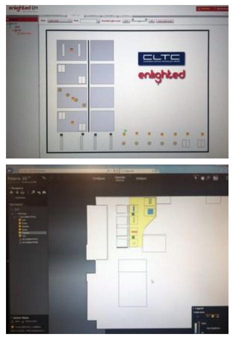
Table 1 Teaching Equipment		
Example of an energy management system	Wireless switch, wireless sensors	Different technology of occupancy sensors
		

Figure 2 | Demonstration sites of adaptive lighting (Source:www.cltc.ucdavis.edu)

Teaching Methods to be Used:

Individual Speaker / Panels

Slide presentation / Other visual aids

Group discussion on appropriate use of lighting controls

Visit to demonstration sites

Recommended Activities

- Visit demonstration site where adaptive lighting is installed and experiment with the control parameters/ strategies
- Discuss common problems and commissioning procedure for occupancy sensors in different applications

APEC Project: EWG 06 2015A

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APEC#217-RE-03.3.