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# Sector Study on Environmental Services: Energy Efficiency Businesses

APEC Policy Support Unit
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## EXECUTIVE SUMMARY

The APEC region represents approximately 60% of the world's primary energy demand. Actions taken in the region play a significant role in determining the world's Greenhouse Gas emissions. All APEC economies have individual energy or emissions intensity targets and have collectively set a target equivalent to reducing energy intensity by 45% between 2005 and 2035.

Energy efficiency (EE) is the provision of more services per unit of energy consumed. Investment in energy efficiency in 2016 stood at $231 billion in 2016, an increase of 9% over the past year. We estimate at least 70% of this investment is in the form of EE equipment, with the remainder on EE services. Energy efficiency services include consultancy, energy audits, finance, design, installation, maintenance, training, and monitoring and verification of energy savings. EE service businesses are dispersed in a number of industry categories under UN CPC.

Energy Service Providers (ESPs) is an umbrella term referring to commercial or non-profit businesses providing a broad range of energy solutions, while ESCOs or Energy Service Companies, are a type of ESP that receive performance-based compensation, depending on energy savings achieved.

ESPs face regulatory challenges such as a bias towards the supply side, lack of recognition of the ESP industry and lack of fiscal support to the industry. The industry may also encounter market challenges such as financial and performance risks, high transaction costs, difficulties in obtaining credit and management challenges such as lack of trained personnel, long project cycles, hurdles doing business across borders and competition with in-house EE teams.

Table 1 summarises key technology trends, policy drivers and sectors of opportunities in APEC for ESPs.

**Table 1. Technologies and Policy Drivers for ESPs in APEC**

| Sectors | Policy Drivers | Technologies | Opportunities for ESPs |
|---|---|---|---|
| Buildings | Minimum Energy Performance Standards (MEPS),<br>Building Codes | Insulation, HVAC improvements, IoT | Opportunities in growing commercial sector- e.g. BPOs in the Philippines |
| Industry | Mandatory energy auditing (Australia)<br>Requirement for large units to have energy managers | Minimising heat losses, Heat recovery through exchangers,<br>Right sizing motors | Less energy intensive sectors such as construction, electronics and food products |
| Transport | Subsidies for new technologies (Japan)<br>Green vehicle subsidy and tax on high consumption vehicles (USA; Hong Kong, China ) | Improving fuel efficiency | Opportunities to partner with utilities for smart charging, Vehicle2Grid |
| Power | Creating energy districts (Russia; and Hong Kong, China) | District heating and cooling, smart grids | Act as district cooling utility |

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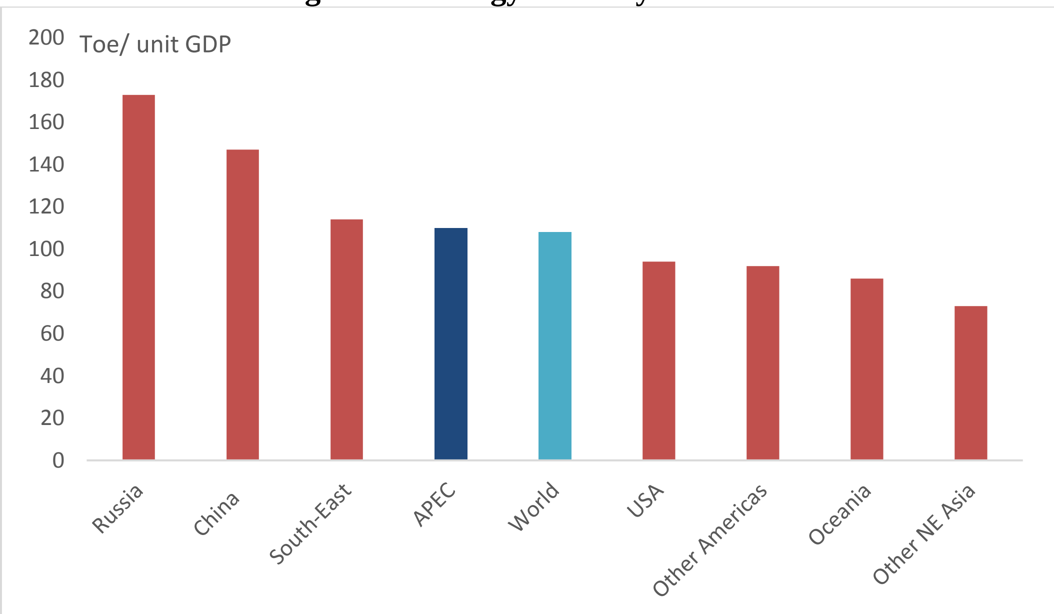
# 1. OVERVIEW OF THE STUDY

## A. BACKGROUND

The APEC region represents approximately 60% of the world's primary energy demand[1] and more than half of global real GDP. Actions taken in the region play a significant role in determining the world's Greenhouse Gas (GHG) emissions.

Energy efficiency (EE) is the concept of providing more desired services per unit of energy consumed. Energy intensity is the amount of energy used to produce one unit of GDP. Figure 1.1 shows the energy intensity in APEC economies and regional groupings, compared to the world. APEC's energy intensity goal is equivalent to reducing energy intensity for APEC as a whole by 45% from 2005 to 2035 (APERC, 2016).

**Figure 1.1 Energy Intensity in APEC**




Note: Toe- Tonnes of oil equivalent
Source: APEC (2013)

Investment in energy efficiency in 2016 stood at $231 billion in 2016, an increase of 9% over the past year (IEA, 2017). We estimate at least 70% of this investment is in the form of EE equipment, with the remainder on EE services.

The American Council for an Energy Efficient Economy (ACEEE) has published an International Energy Efficiency Scorecard that examines the energy policies and performance of 23 of the world's top energy-consuming economies. Economies were evaluated and scored on efficiency policies and how efficiently their buildings, industry, and transportation sectors use energy. As seen in Table 1.1 Five APEC economies ranked among the top 10 energy efficient economies: Japan; China; Korea; United States; and Canada.

[1] According to U.S. Energy Information Administration data reported in 2016, APEC economies consumed approximately 342 quadrillion BTU (British Thermal Units) or 62% of the world's primary energy in 2014.

**Table 1.1 Efficient Economies Ranking, 2014**

| Ranking | Economy |
|---|---|
| 1 | Germany |
| 2 | Japan |
| 2 | Italy |
| 4 | France |
| 5 | UK |
| 6 | China |
| 7 | Spain |
| 8 | United States |
| 8 | Korea |
| 10 | Canada |
| 11 | Netherlands |
| 12 | Poland |
| 13 | Chinese Taipei |
| 14 | India |
| 15 | Turkey |
| 16 | Australia |
| 17 | Russia |
| 18 | Indonesia |
| 19 | Mexico |
| 20 | Thailand |
| 21 | South Africa |
| 22 | Brazil |
| 23 | Saudi Arabia |

Source: ACEEE (2016)

The scorecard indicates that there is a robust market for EE goods and services in the major APEC economies. In the region's smaller economies, there is substantial potential to expand EE services.

## B. OBJECTIVES

This study aims to build and enhance the understanding of energy efficiency services among APEC economies, with a view to identifying key challenges. The study is expected to contribute to the implementation of Phase 1 of the Environmental Services Action Plan (ESAP) and subsequent works of the action plan. Understanding and addressing challenges and opportunities faced by energy efficient equipment manufacturers and service providers will empower APEC economies to rapidly employ energy efficiency and conservation (EE&C) strategies.

The primary objectives of this report are to:

- Provide an overview of the EE sector and types of EE service providers
- Analyse the major trends in demand and technology in EE services in APEC economies
- Identify the business models under which EE service providers operate
- Identify major players in APEC economies
- Identify the regulatory challenges faced by these businesses
- Highlight the opportunities in the sector

## C. INSIDE THIS REPORT

Section 2 of the report has a detailed analysis of Energy Efficiency Service Providers (ESPs)-business models, market conditions and challenges facing the sector. This section includes the interactions between ESPs and other EE stakeholders. Section 3 describes technology trends in the EE market. Section 4 looks at the demand drivers and opportunities facing the EE services sector, followed by concluding remarks in Section 5.

# 2. EE SERVICES INDUSTRY BUSINESS ANALYSIS

This section describes the EE Services industry. The first part contains an analysis of the scope, types and business models of EE service providers. The second part looks at market conditions for ESPs in APEC. The third part analyses regulatory and market challenges facing the sector.

## A. INDUSTRY CLASSIFICATION

Energy efficiency investments are important in combating climate change in the following ways:

1. By reducing energy consumed, lower Greenhouse Gas (GHG) emissions are produced. Studies have shown that standard EE interventions can reduce energy consumption and GHG emissions by 20%.
2. GHG emission reductions can be achieved at lower cost, since energy efficiency acts as a low-cost resource, requiring much lower investment than setting up a new source of energy supply (EPA, 2009).

Energy Efficiency Service Providers (ESPs) are a vital part of the energy efficiency market. They are businesses that help their clients reduce energy consumption and costs by providing some or all of the following types of services:

- Consultancy
- Energy audits
- Finance
- Design
- Equipment installation
- Maintenance
- Training
- Monitoring and verification of energy savings

Currently, depending on services provided, and the level of vertical integration, ESPs are dispersed under the following UN CPC[2] categories (UNStats, 2017):

- 1710 Electrical Energy
- 512 Construction work for buildings
- 513 Construction work for civil engineering
- 514 Assembly and erection of prefabricated constructions
- 516 Installation work
- 517 Building completion and finishing work
- 811 Financial intermediation services, except insurance and pension fund services
- 831 Leasing or rental services concerning machinery and equipment without operator
- 867 Architectural, engineering and other technical services
- 879 Other business services
- 94090 Other environmental protection services

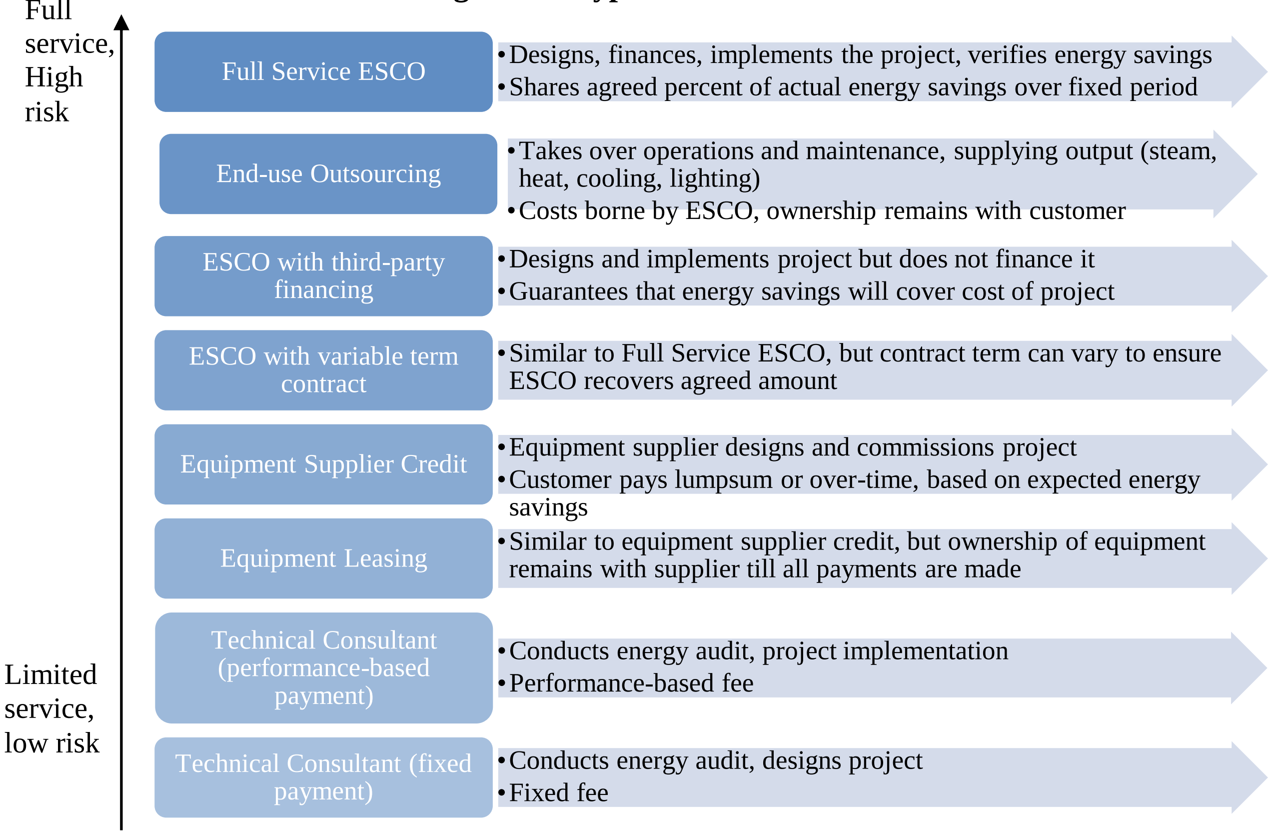
[2] UN CPC version 2.1

## B. TYPES OF ESPS

Energy Efficiency Service Providers (ESPs) is an umbrella term referring to commercial or non-profit businesses providing a broad range of energy solutions including design and implementation of energy saving projects, retrofitting, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management. The presence and size of the ESP market in an economy reflects the efforts to advance energy efficiency through effective business models and creative financing.

ESCOs or Energy Service Companies, are a specific type of ESP that receive performance-based compensation, depending on energy savings achieved. The distinction between ESCOs and other ESPs that act as advisories is not clear-cut, as practices may differ across economies, and firms may change the scope of their work depending on market demand. Energy efficiency businesses may be owned by companies, utilities or the Government. They can be commercial or non-profit entities.

**Figure 2.1 Types of EE Service Businesses**




Sources: World Bank (2010); (MP Ensystems & IIEC , 2017)

ESCOs provide some or all the services listed below (European Commission, 2003):

- Energy audits
- Feasibility studies
- Engineering design
- Equipment procurement

- Subcontractor management
- Construction
- Measurement and verification
- Operation and maintenance
- Project Financing

While features of ESCOs vary among APEC economies, the defining feature of these businesses is Energy Savings Performance Contracting (ESPC). The main features of ESPC are:

- The contract states that payments are dependent on results
- The contract recognizes ownership of risks
- It acknowledges responsibilities
- Baseline energy consumption is established and documented in the contract
- It documents the equipment to be installed
- The term of the contract is established
- Identifies monitoring and verification (M&V) requirements

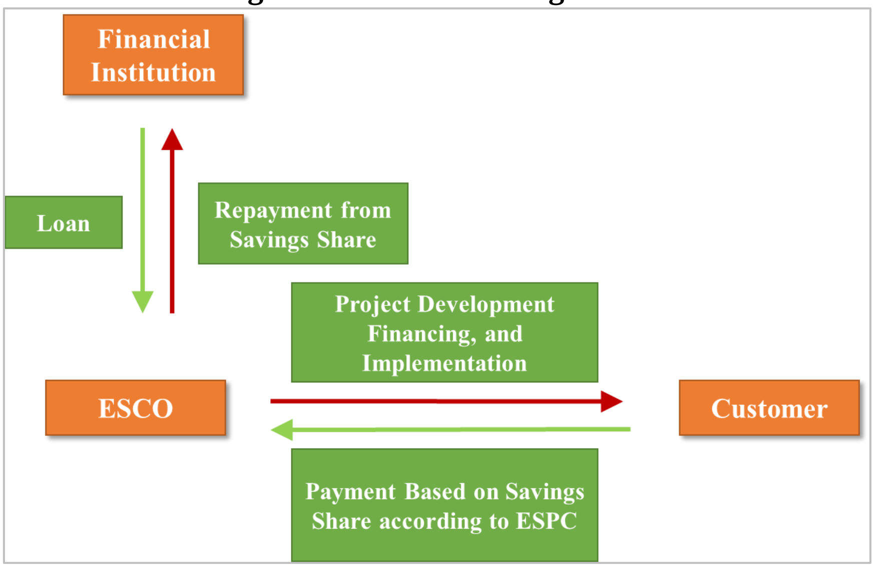
## C. ESP BUSINESS MODELS

ESP firms that act as consultants and charge clients for their EE services have a similar business model to other advisories and consultancies. ESCOs have two main business models- Shared Savings and Guaranteed Savings.

### i. Shared Savings Model

Under the shared savings model, the ESCO finances the project, without investment from the consumer. The ESCO and consumer share the financial savings due to reduced energy consumption in a defined ratio, over the contract period.

**Figure 2.2 Shared Savings Model**

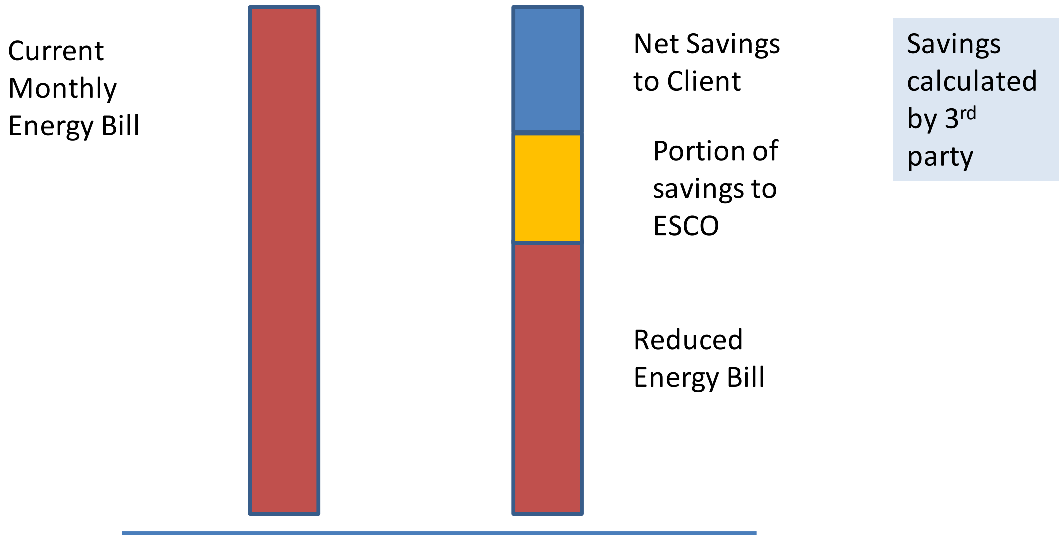



Source: UNECE (2014)

*Case Study: Shared Savings Model in Singapore*

An ESCO in Singapore replaces the controllers in building chiller plants and uses the data from the controllers to optimize the operation of the chiller plant equipment and reduce the energy consumption of the building. The client does not pay upfront, instead the baseline energy consumption is measured and energy savings are monitored by an independent third party. The ESCO receives its payment from these savings, as shown in Figure 2.3 below.

**Figure 2.3 Shared Savings model by ESCO in Singapore**

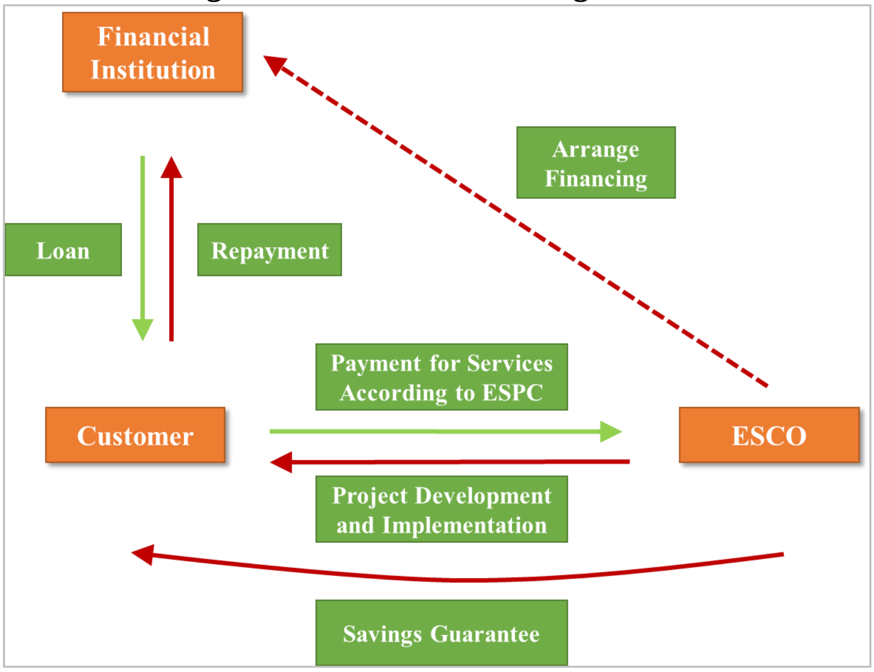



Source: BBP Singapore (2017)

### ii. Guaranteed Savings Model

Under the guaranteed savings model, the customer finances the project, while the ESCO provides a performance guarantee. The ESCO is paid once the facility achieves the desired efficiency level. This model is undertaken when the customer has easier access to capital than the ESCO. Figure 2.4 shows the flow of funds in a Guaranteed Savings model.

**Figure 2.4 Guaranteed Savings Model**




Source: UNECE (2014)

*Case Study: Guaranteed Savings model in Korea*

In Korea, approximately 74% of buildings were constructed over 20 years ago, a majority of them were inefficient. Hence, there is considerable potential for ESCOs to enhance EE of buildings. In this case study, an ESCO carried out insulation and window retrofits to improve the efficiency of a commercial building (Hyein Yi, 2017). The project details are in Table 2.1.

**Table 2.1 ESCO Project Details**

| | |
|---|---|
| **Project cost** | 462,000 USD |
| **Target savings** | 75,600 USD/year |
| **Guaranteed savings** | 60,480 USD/year |
| **Expected savings** | 66,528 USD/year |
| **Performance guarantee period** | 8 years |

Source: Hyein Yi (2017)

The target energy savings and guaranteed savings levels were proposed by the ESCO. An external agency verified the value of the expected energy savings. Using the interest rate and inflation, a discount rate was calculated and this was used to determine the period of the project- 8 years. An estimate was made for volatility due to change in electric and gas usage (the price of gas and electricity were fixed at the time of the contract). The project also included Certified Emissions Reductions (CERs) as a part of the savings accruing to the customer (Hyein Yi, 2017). This project is currently underway, hence the final savings are not known.

### iii. Other ESP Business Models

ESPs that do not work under performance contracting typically carry out EE services and are paid for them. The payments may not be linked to energy savings. Some of these types of businesses are in Table 2.2.

**Table 2.2 Types of ESP Businesses**

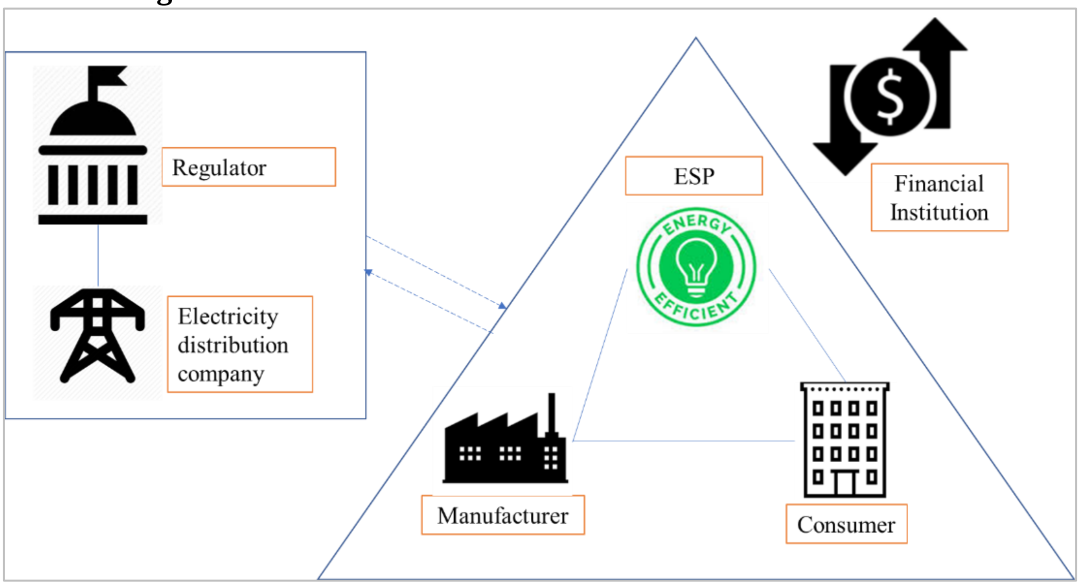
| Businesses | Services Provided for a Fee |
|---|---|
| Consultancies and advisories | Provide technical inputs on process and management changes, |
| Energy Auditors | Measure and meter energy consumption of premises, provide comprehensive report on recommended EE measures, costs, expected savings |
| Product suppliers | Use EE services as a sales and marketing tool, and provide finance for customers to purchase their products and services |
| Contractors | Procure and install EE equipment |
| Design firms | Provide inputs for new or existing green building design |

Source: (MP Ensystems & IIEC , 2017)

## D. INTERACTIONS BETWEEN ESPS AND OTHER MARKET STAKEHOLDERS

Figure 2.5 shows the relationship between ESPs, manufacturers, electricity distribution companies. This interaction is described in the section below.

**Figure 2.5 Interaction between ESPs and other Stakeholders**




Source: (MP Ensystems & IIEC , 2017)

### i. Interaction between ESPs and Manufacturers

Investment in energy efficiency in 2016 rose 9% to $231 billion in 2016 (IEA, 2017). We estimate at least 70% of this investment is in the form of EE equipment, with the remainder on EE services. US, China and Southeast Asian APEC economies are a manufacturing hub for the world's EE equipment, including LEDs, air-conditioners and electric vehicles. Appendix III contains a list of the major manufacturers and suppliers of EE equipment.

Manufacturers and ESPs are closely linked, with some ESPs owned by manufacturers, others working in partnership with certain manufacturers. Most topics covered in this report- demand drivers, technology trends, regulatory environment, opportunities and challenges that affect the ESP industry, equally affect the manufacturers of efficient equipment.

The case study below highlights the synergy between ESPs, manufacturers and electricity distribution companies in implementing large-scale energy efficiency projects.

*Case Study: Efficient Lighting Initiative*

The Efficient Lighting Initiative (ELI) is a World Bank sponsored program that promotes the manufacture, distribution and installation of EE lighting in a number of economies, including APEC economies Peru; China; Viet Nam; and the Philippines. At the onset of this program in 2009, compact fluorescent light bulbs (CFLs) were procured from manufacturers and distributed to consumers in exchange for less efficient incandescent lightbulbs. Manufacturers such as Anhui, GE, OSRAM, and Philips were certified by the China Standard Certification Center to meet technical and performance criteria. The institute considered criteria set by ESPs and electricity distribution companies during their procurement process, while setting these standards. The actual procurement and distribution of the CFLs was conducted differently across economies. For example, in Viet Nam, bulk procurement was carried out from manufacturers and the CFLs were sold by distribution companies. In other economies, market channels (distributors and retailers) were used to promote the sale of CFLs.

Some results of the program:

- 20-fold increase in sale of CFLs in Peru
- Price reduction of CFLs (up to 85% in Argentina)
- Market shift towards higher quality CFLs in the Philippines
- Thousands of trained efficient lighting experts
- Energy consumption reduced by 2,590 gigawatt-hours (GWH), and $CO_2$ emissions by 2,018,000 tonnes between 2000- 2003 (IFC, 2005)

Source: (World Bank, 2009)

### ii. Interaction between ESPs and Electricity Distribution Companies

Electric distribution companies supply energy to consumers, while ESPs work with consumers to reduce energy demand. Despite these opposing goals, the two industries work together in the following ways:

1. Subsidiary: ESPs may be subsidiary arms of electricity distribution companies. They participate in utility Demand Side Management[3] (DSM) programs, provide efficiency services at a discount, or act as for-profit entities.

[3] A Demand Side Management program is conducted by utilities to reduce energy consumption on the consumer side of the meter. DSM activities include planning, implementing, and monitoring energy savings, which can be conducted by the utility or an ESP.

2. Contractor: Utilities may hire ESPs as contractors or partner with them for DSM programs

3. Competitor:
   i. In some economies where the electricity sector is deregulated, large energy consumers may purchase energy from ESPs that have become energy suppliers. In this case, ESPs directly compete with utilities in their core area of business.
   ii. In the case of an energy efficiency power plant, an ESP invests to reduce energy consumption in a measurable and predictable way that can be compared to the output of a convention power plant. To produce "negawatts" or energy savings, the ESP carries out load management, DSM and Demand Response activities among a set of consumers. Demand Response is a program in which energy consumers reduce or shift their electricity load during peak hours in response to Time of Use rates, or other financial incentives. (Limaye, 2010). In this way, the ESP competes with the utility in supplying energy.

*Case study: ESCO Standard Offer program for Commercial and Industrial consumers, Centerpoint USA*

A Standard Offer Program (SOP) is a utility program in which an ESP (or other aggregator firm) implements energy efficiency measures (EEMs) at the consumer end, producing negawatts (saved energy/demand or both), which can be purchased by the utility. Centerpoint, a US-based utility has implemented an SOP, with the following features:

Sponsors: ESPs, engineering and architecture firms, contractors or private individuals can act as project sponsors, by installing EEMs at Centerpoint consumer locations in non-residential buildings.

Consumers: Government, commercial and industrial consumers of Centerpoint can take part in the program.

Project: Measures installed at a location must reduce peak demand by at least 20 kW or generate annual energy savings of at least 120,000 kWh.

EEMs: Eligible EEMs include improving HVAC efficiency by replacing a chiller, cogeneration projects, replacing inefficient lights with efficient fluorescent or LED lights etc.

Payments: Project sponsors can be paid in the following ways:

1. Incentives paid for specific measures (such as changing light fixtures), post installation and verification
2. For certain measures (such as fuel switching from electric to gas), measurement and verification is conducted for a year’s savings, before the project sponsor is paid

Savings achieved: Until June 2015, over 100 projects were implemented, with a 15 MW reduction in peak demand.

Source: (CenterPoint Energy, 2015)

### iii. Interaction between ESPs and Regulators

Electricity is a regulated industry in most APEC economies and the role of the electricity regulator is to promote public interest, through its rate-making and rule-making functions. When an ESP conducts its activities with households or businesses as its customers, typically the electricity regulator has no role to play.

However, rules set by the regulator or other Government agencies on energy efficiency appliance labels, buildings energy ratings, DSM or other efficiency programs affect the functioning of ESPs. Additionally, in many economies, the regulator or a Government agency empanels or certifies ESPs, based on criteria such as financial strength, projects performed and energy savings achieved, and number of trained personnel.

For example, the Malaysian Energy Commission (Suruhanjaya Tenaga) is a statutory body created under the Energy Commission Act 2001 to regulate the energy sector. Its main role is to carry out economic, technical and safety regulation of the electricity and piped gas industries. In addition, it is responsible for registering and accrediting ESCOs (Energy Commission, 2017).

Some economies outside APEC, e.g. UAE, have set up special regulatory bodies for ESPs, in order to streamline ESP activity and meet a national energy efficiency target. The role of such a regulator is to certify ESPs, standardise M&V methodologies, provide standards for energy performance contracting and set up a dispute resolution mechanism (RSB, 2017).

**iv. Interaction between ESPs and Consumers**

Consumers working with ESPs to reduce their energy consumption follow one of the options below, depending on their access to funds, credit worthiness, business viability and risk appetite:

- Fees: Hire ESP to improve EE of the premises and pay on completion of work
- Guaranteed savings: Consumer pays for the EE improvements, the ESP provides a guarantee of energy savings and is paid when savings are achieved, leading to a reduced risk to consumer
- Shared savings: ESP pays for EE project and is paid out of the energy savings
- Third party financing- The ESP or consumer borrow funds from a financial institution and repay it from the savings generated by the EE project

Although 90% of global enterprises are SMEs and their economic contribution varies between 15-50% of an economy's GDP (IFC, 2012), ESPs mainly work with large commercial, industrial, public and institutional consumers. Residential, small commercial and micro small commercial and small and medium enterprise (MSME) consumers are typically under-served. Reasons for this include the higher cost to ESPs of servicing multiple consumers (eg individual apartments in a building, number of SMEs in a cluster), lack of consumer awareness and the inability of these consumers to make large upfront payments.

**v. Interaction between ESPs and Financial Institutions**

EE services are financed from one of the following sources:

- Consumer funds the EE services and equipment through own balance sheet
- Consumer borrows from a financial institution
- Institutional consumer issues a bond to finance EE
- ESP using performance contracting funds project through own balance sheet
- ESP using performance contracting borrows from a financial institution
- ESP and/or consumer access Government or donor agency ESP fund

*Case Study: Green Technology Financing Scheme, Malaysia*

Under this program, the government provides an interest susidy of 2% for loans taken to purchase green technology. It also provides loan guarantees for 60% of the loans. Any technology promoting GHG emissions reductions can qualify for this program. Technology suppliers and consumers can avail these loans, up to a limit of USD 23 million for producers and USD 3.1 million for consumers. Projects are monitored by GreenTech Malaysia.Until 2015, 6 banks used the funds to finance 57 projects in Malaysia, providing a fillip to the energy efficiency sector and ESPs. However, the program did not specifically target ESPs (European Commission, 2014).

EE implementation and volume of business conducted by ESPs is expected to grow faster if financial inflows to the sector increase. Section 2.6.2 provides details on why ESPs face difficulties in accessing finance.

## E. EE SERVICES MARKET IN APEC

The table below provides a snapshot view of the ESP sector in select APEC economies.

**Table 2.3 Snapshot of ESPs in APEC**

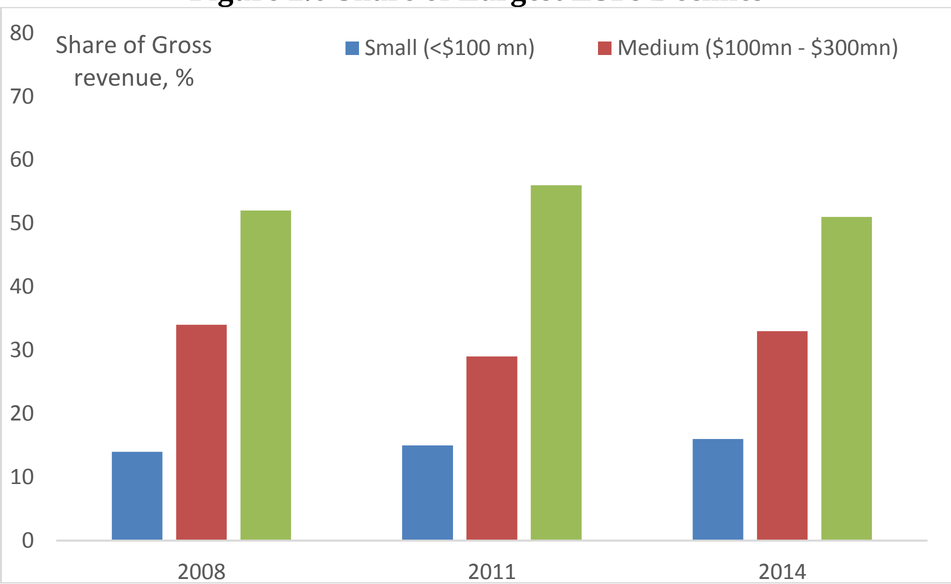
| | **Viet Nam** | **Thailand** | **China** | **United States** | **Australia** |
|---|---|---|---|---|---|
| **Number of ESPs** | About 20 existing ESPs could act as ESCOs, but only a few have implemented ESCO projects so far. | 45 registered ESPs, about 10 of them work under EPC | 5246 ESCOs (2015) | 144 ESCOs | 12 ESCOs |
| **ESP market size and potential** | There is an increased focus on ESCOs' business in government policy, but it is not possible to define a market trend as the ESCO market has not taken off | Market size around USD 100-200 million in 2012. Market potential around USD 500 million in 2012 (Leaver, 2013). | ESCO revenues of USD 13.3 Bn in 2015. Currently ESCOs employ over 600,000 people. | $6.4 billion (2013); Remaining market potential estimated at $71- $133 billion | $72,587,386 (total value of EPCs implemented in the financial year 2013- 2014); no information available on the existing market potential. |
| **ESCO market trend** | Growing | Growing | Poised for rapid and sustained growth, with the market growing at 7% in 2015 | Steady to high growth rate expected | Slightly decreasing in the last year |
| **Main type of contract** | EPCs with shared savings (first-out approach). | EPCs with guaranteed savings, BOOT contracts (not very frequent) | Shared savings | Performance-based (e.g., guaranteed savings), design-build, onsite generation PPA, consulting, utility program administration, other | EPCs with guaranteed savings, BOOT contracts, chauffage contracts |
| **Typical ESP projects** | Demonstration EPC projects carried out in food processing facilities. There is potential for project implementation in energy intensive industries such as cement, iron, steel, chemical, pulp and paper industries | Projects mainly implemented for industry. Technologies and fields of application: pumps, electric motors and inverters, CHP, lighting, air conditioning. | Industrial sector accounted for 80% of the demand, followed by buildings (in 2011). Technologies employed include- variable speed controls, central air conditioning, waste heat power generation | Energy conservation measures (lighting, control, etc.), onsite renewable generation, other, consulting, engines/turbines | Public buildings (higher education facilities and hospitals). Installation of energy efficient lighting solutions, HVAC solutions. Co-generation and tri-generation in the commercial and industrial sector. |
| **Source** | (European Commission, 2014) | (European Commission, 2014) | (IFC, 2012) | (European Commission, 2014) | (European Commission, 2014) |

### i. ESPs in APEC: Trends

Among APEC economies, United States; Japan; and Canada have long-standing ESP industries, while those of China; Chinese Taipei; Korea; Thailand; Viet Nam; and Singapore are rapidly developing (European Commission, 2014). Major trends observed in the ESP market are

1. Major market players
   In the United States, the market share of the eight largest ESPs[4] has reduced between 2006 and 2014, as seen in Figure 2.5 (Charles Goldman, 2005). In contrast, smaller economies such as Indonesia have approximately 15 ESPs, which include state-owned companies, manufacturers and multinationals, none of which dominate the market (European Commission, 2014).

**Figure 2.6 Share of Largest ESPs Declines**




Source: LBNL (2016)

2. New entrants
   In developed economies, utilities are increasingly providing energy efficiency services in order to bolster revenue that has been hit by a low energy demand outlook. Additionally, due to the use of remote monitoring and control, new firms are entering the ESP market to sell energy solutions, that include EE services, program design, marketing, data analytics, strategic energy management, policy advisory, market research and training (Charles Goldman, 2005).

3. Regional disparity
   In mature markets such as the United States, ESPs are concentrated in states with high economic activity. (LBNL, 2016). In developing economies, location and growth of ESPs is dependent on local Government support.

[4] Appendix I contains a list of the major market players in APEC

4. Sources of finance
   In the US, ESPs use loans and leases to finance Government projects, and used bonds to raise funds for institutional consumers (LBNL, 2016). In developing economies, ESPs finance projects from their working capital, Government ESP funds, international grants and commercial bank loans.

## F. CHALLENGES FACING THE ESP INDUSTRY

### i. Regulatory Challenges

Regulatory challenges encountered by ESPs in APEC economies include:

1. Bias towards supply side
   While developing infrastructure plans, governments typically undervalue the importance of energy efficiency in enhancing productivity and have a bias towards energy supply options. Energy planners may overestimate future energy demand and exclude the option of EE as an energy resource to meet demand.

2. Lack of recognition and understanding of the ESP industry
   Because of the supply side bias, the government may have limited interest in employing ESPs to carry out projects on public infrastructure. Governments may not recognize or understand the ESP industry, may not support ESP associations, or not recognize ESP accreditation. This may lead to a lack of regulation or over-regulation of the EE services industry, which can hurt ESP growth.

   For example, in some economies as a part of government plans to promote energy efficiency in public buildings, the duration and share of energy savings for performance contracting are predetermined, even before the investment-grade energy audits can be conducted, leading to lack of participation by ESPs in the project. Indonesia is an example where policies on energy efficiency, management and audits have been in place since 2009, but these have not yet been sufficient to create significant demand to promote energy efficiency business and energy efficiency projects (World Business Council for Sustainable Development, 2015). .

3. ESPs and government buildings
   Public procurement of energy services is a large, untapped target for efficiency improvement. ESPCs can be beneficial to government agencies in implementing EE in public buildings and facilities since the entire work can be outsourced to the ESP, skipping the slow process of procurement. Additionally, by using performance contracting, ESPs can pay for the services through savings, which can be an attractive, low-risk proposition for cash-strapped government agencies. However, many economies have rigid rules for procurement - performance contraction may not be specified as an option and EE may not be a criterion for appliances, limiting the role of ESPs in government facilities (ESMAP, 2010). For example, Indonesia's government procurement rules rely mainly on selection of the lowest cost bidder, and projects have two different bids on project design and implementation, which restrict the role an ESP can play (European Commission, 2014).

4. Taxes
   Economic incentives such as tax credits, subsidies and rebates for ESPs can be an important instrument for promoting investment in EE products and services. These incentives, when paired with efficiency standards and labels can help businesses overcome the barrier of higher cost of efficient appliances. While some economies have put in place tax incentives (See Section 3. Policy and Regulatory drivers for a description of tax incentives), these are not in place in many APEC economies. For example, the Philippines has not provided tax incentives to develop its nascent ESP industry.

### ii. Market Constraints

EE businesses face the following types of challenges in the marketplace:

1. Business risks
   i. Financial risk- The credit-worthiness of the consumer and the state of the economy could affect the consumer's business and ability to pay the ESP. To minimise this risk, ESPs may choose to work only with credit-worthy consumers that are expected to have long-term stability, such as municipalities and universities (Columbia University, 2014).
   ii. Technology risk- The energy end-use selected (e.g. installing plug and play LED lighting vs HVAC equipment retrofit) affects whether the project requires limited expertise, has low chances of failure, is less affected by external factors such as weather and occupancy determined and is low risk.
   iii. Performance risk- Related to technology risk is the risk that there is a gap between the potential savings and actual savings achieved by a project.

2. Transaction costs in Performance Contracting

   Performance contracting entails transaction costs such as:
   - Cost of developing baseline over a period
   - Developing M&V plan using an appropriate methodology[5]
   - Cost of metering to measure energy consumption of new EE appliances
   - Using third party to verify savings
   - Legal costs of enforcing contract (if required)

   Each of these steps requires time, financial and human resources, adding to the cost of the EE project. In addition, performance contracting requires information or forecasts on production, occupancy and weather during the metering period.

3. Financial Challenges
   In some APEC economies (e.g. Chinese Taipei; Indonesia; Malaysia; Viet Nam; and Brunei Darussalam) energy prices are heavily subsidized to stimulate economic growth, reducing the return on energy efficiency investments.

[5] The International Performance Measurement and Verification Protocol (IPMVP) has proposed standard methodologies that can be used to conduct M&V of energy efficiency projects. Trained personnel who are certified IPMVP professionals

The high up front cost of EE projects (excluding projects executed under the shared savings model), with benefits expected over a period of 1 to 10 years (depending on the project) deters consumers from taking them up. The high transaction costs make smaller EE projects implemented under performance contracting unviable.

Only ESPs with a strong track record may be to access financing for performance contracts, the others are limited to investing their own funds. Additionally, the perceived risks (described above), drive up the cost of borrowing for EE. And there is a lack of understanding of performance contracting and the ESP business by local banks and financial institutions in Asia.

One way for the ESP market to expand would be by pooling ESP contracts and securitizing them. However, securitization is based on predicting defaults based on a homogeneous pool of assets, and ESP contracts are tailored to the demands of each consumer and the risks vary based on consumer, technology and contract (Columbia University, 2014).

4. Management challenges
   EE services businesses face management challenges that are unique to their business. In economies where the EE services market is not well developed, firms lack manpower with technical competence, leading to opportunities for EE far greater than those actually implemented. In addition to technical skills, firms need to be skilled in building relationships with consumers based on trust and credit worthiness. A lack of skilled manpower, in combination with lack of standardized procedures in energy audits and M&V and lack of legal remedies if performance guarantees are not met, have led to mistrust of the business among potential clients (European Commission, 2014).

   Another challenge facing EE services businesses is the long project cycle. ESPs invest significant time and manpower on new consumers, by conducting audits, educating the consumer and in preparing recommendations. If the project is canceled, they may not be able to recoup these costs.

   ESPs prefer to work with larger consumers, as only these projects may be commercially viable, given the transaction costs. However, larger firms have dedicated facility management teams that may require ESP inputs in design and technology selection, but will be able to complete the project installation on their own, using their preferred vendors.

   As discussed earlier, the ESP business depends on not only technical skills, but also ability to raise finances and deal with consumers. The ESP needs to develop relationships with consumers that relies on trust and credit-worthiness.

5. International services
   A number of ESPs working internationally- while the larger ones have set up local offices, others face additional hurdles at all stages of business development and project implementation. For example, an ESP based in South-East Asia that provides EE products and services across the region needs to overcome the following hurdles that lead to delays and increased costs. Procuring visas for a multinational team adds to the timeline and cost of the project. Additionally, for business visas ESPs require a letter of invitation, which may be difficult to procure when making an initial sales pitch. Firms that do not have local offices face additional hurdles during the measurement stage, as cross border transportation of equipment may be difficult and only local contractors may be allowed to work on site.

The location of signing the contract may also affect the tax jurisdiction of the project, adding costs and complexity. Uncertainty and delays may occur due to lack of clarity of import tariff on pre-programmed equipment and different tariffs on provision of goods and services and customs clearance may add to the delay. Cross-border payments, rules on permanent establishment, tax withholding, and capital requirements for incorporation in multiple economies are additional barriers faced by smaller ESPs (BBP Singapore, 2017).

# 3. EE TECHNOLOGIES

In Section 3, we review trends in energy efficient technologies in buildings, industry, transport and the power sector.

## A. TRENDS IN EE TECHNOLOGIES

This section details the technology trends in the buildings, industrial, transport and power sectors and case studies of applications of these technologies. Table 3.1 summarizes the EE measures that are applicable to the relevant sectors.

**Table 3.1 EE Sectors and Measures**

| Sector | EE Measures |
|---|---|
| Residential and Commercial buildings | • Efficient lighting, HVAC and appliances<br>• Adjustments in use patterns<br>• Using appropriate construction materials for new and retrofitted buildings<br>• Maintenance and monitoring |
| Industrial | • Data collection, regular analysis of energy performance<br>• Combustion control and instrumentation of boilers and furnaces<br>• Minimize heat loss in industrial processes<br>• Waste heat recovery<br>• Installing efficient motors, boilers, pumps, fans |
| Transport | • Vehicle-to-Grid system |
| Power Sector | • Distributed generation: District Cooling and Heating<br>• Smart Grid: Big data, smart meters |

### i. Buildings

Buildings account for 30-40% of total energy consumption in most economies (IEA, 2017). Within buildings, the major energy applications and new technologies in these areas are provided in Table 3.2 below:

**Table 3.2 Emerging Efficient Technologies in Residential and Commercial Buildings**

| End use | Technology | Description |
|---|---|---|
| Nearly Net Zero Energy Building (NZEB) | Green Building Materials | An NZEB is a building where the annual energy used by the building is close to the amount of renewable energy created on the site. NZEB requires integration between building design (location, materials, envelope, insulation) and use (heating, ventilation and air conditioning (HVAC), lighting, appliances). New green building materials include bioplastics, structural 3D printing, cool roof paints, window coatings, unconventional insulation materials etc. |
| HVAC | Heat Pumps | These have the technical potential to save 50% of energy used by conventional HVAC technologies in residential buildings. New technologies include heat exchangers, advanced refrigerators, air conditioners and clothes dryers that generate waste heat, and non-vapor compression technologies (EERE, 2017) |
| Lighting | Solid State Lighting | As use of LEDs, OLEDs and PLEDs[6] rises, energy savings of 75%, lower maintenance and more uniform light distribution can be achieved (EERE, 2017) . Sensors for daylight and occupancy, use of a Building Monitoring System and lighting connected via IoT can improve productivity and efficiency. |
| Appliances | Internet of Things (IoT) | Smart homes and lighting automation are all expected to occur as appliances become connected to the internet. Using applications, these could lead to lower energy consumption. However, mains-connected IoT appliances may consume additional stand-by power in order to always remain online (IEA, 2016). |
| Appliances | Behavior Based Energy Efficiency (BBEE) | BBEE programs achieve energy savings due to changes in individual or organizational behavior. Examples include providing residential consumers with information on their energy use, comparisons with usage of others, goal setting and rewards. Another example- helping commercial end-users benchmark their building’s energy use and improve operating performance through changes to O&M practices. |

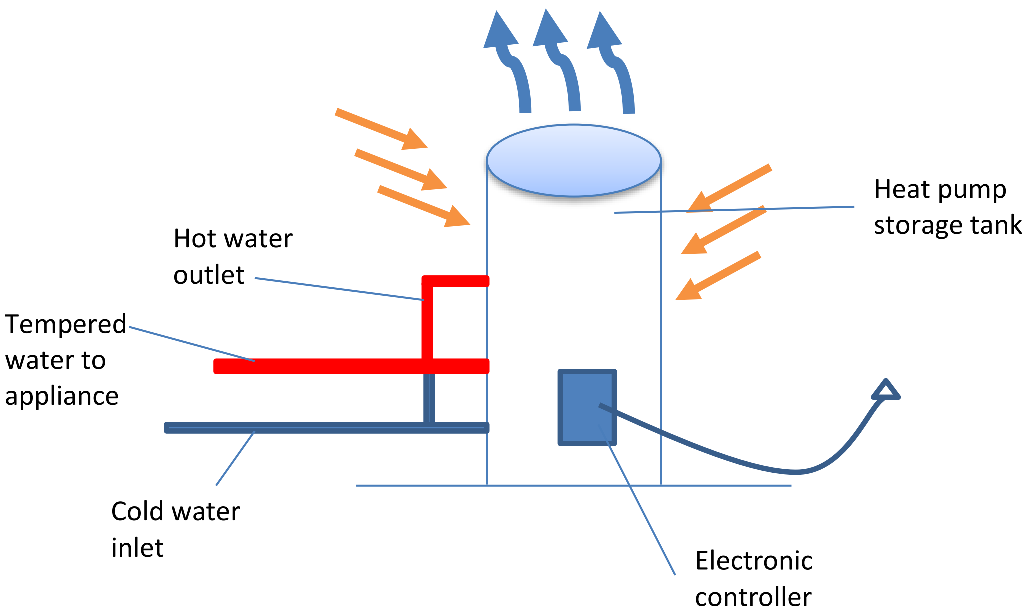
Sources: IEA (2016), EERE (2017), and EERE (2017)

[6] Light emitting diode (LED), organic light emitting diode (OLED), polymer LED (PLED).

*Case Study: Heat Pump and Solar in Australia*

The city of Sydney sponsored a study to test the optimum energy saving option for water heating and lighting common areas in residential buildings. In a 5-storey residential building that had an existing gas water heating system and some roof, a comparative study of solar PV, solar thermal, gas and heat pump was conducted. Given the existing conditions (rising gas prices, local climatic conditions, small area available for solar panels), installing an electric heat pump system with 10kW solar PV panels was found to be the optimum solution for lighting and heating in the common area, leading to a 26% reduction in electricity bills. Combining a heat pump with the gas water heating system allowed slow heating of water and the use of off-peak hours to heat water. If such a system were widespread, by absorbing warm air, it would also make a dent in the urban heat island effect[7] (Edmunds, 2017). Figure 3.1 shows the working of a heat pump.

**Figure 3.1 Diagram of Heat Pump**



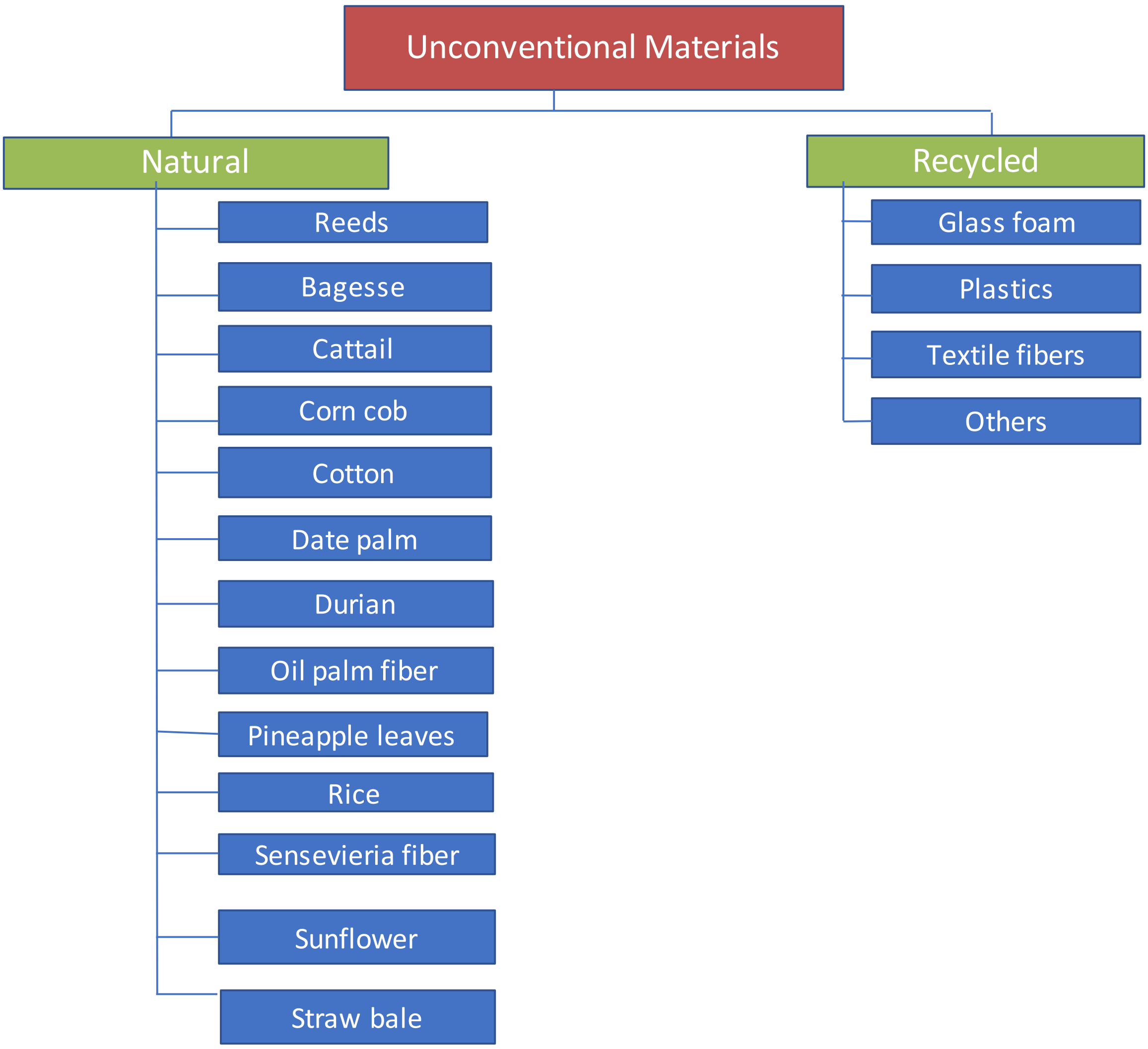

Source: Energy Rating Australia (2017)

[7] The urban heat island effect is when temperatures of an urban area are 1-2 degrees Celsius higher than the temperature in neighbouring rural areas, mainly due to modification of land surfaces and waste heat generated from energy use.

*Case Study: Insulation using unconventional materials*

Building insulation helps keep energy bills low, by maintaining the desired conditions indoors. Conventional building insulation is made of petrochemicals, or from natural sources that require high energy consumption to produce (glass and rock wools). In addition, it may be linked to health hazards. Research on low-cost, unconventional materials that provide thermal and acoustic insulation, with low embodied energy and easy end-of-life disposal are included in Figure 3.2.

**Figure 3.2 Unconventional Energy Efficient Building Materials**




Source: Francesco Asdrubalia (2015)

While the value of these insulation materials has been recognized, they require more research on durability, fire resistance, water vapour diffusion and fungal resistance.

*Case Study: Reducing energy consumption of IoT connected appliances*

The Internet of Things (IoT) is a network of connected physical objects that are accessible through the internet. IoT may have a number of applications, including enhancing energy efficiency. However, having these devices always connected, even when not required for their primary function requires stand-by power. Although the standby power consumption of a single device is low, the impact of millions of connected devices is expected to be sizeable. Table 3.3 has an estimate of standby power consumption of commonly used devices.

**Table 3.3 Standby Power Consumed by IoT Devices**

| Category | Device | Average Standby Power (W) |
|---|---|---|
| Smart Lighting | Smart LED bulbs | 1.0 |
| | Gateways | 1.6 |
| Home Automation | Gateways | 1.7 |
| | IP Camera | 2.2 |
| | Mains connected Sensors | 0.6 |
| | Mains connected Actuators | 1.0 |
| Smart Appliances | Appliances | 0.4 |
| | Gateway | 1.6 |

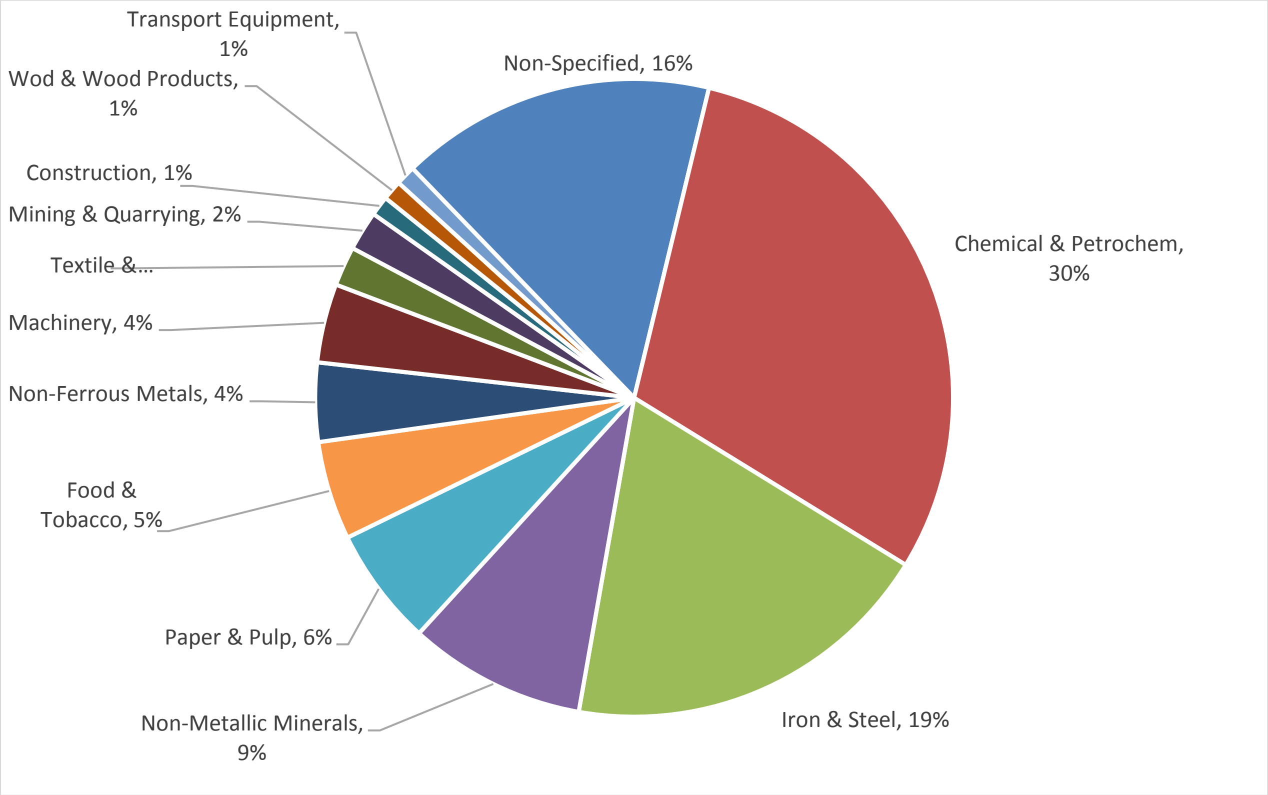
Source: IEA (2016)

An analysis of existing communication technologies shows that appliances have a wide range of levels of standby power consumption. Technologies with low standby power are already established, mainly in battery-powered edge devices. The major energy saving standards for power communication that already exist are IEEE 802.15.4, IEEE 802.3az (EE Ethernet, Wake-on-LAN (WOL), Wi-Fi (IEEE 802.11). These standards need to be applied to mains-connected appliances used in residential and commercial buildings (IEA, 2016).

### ii. Industry

In the industrial sector, energy is purchased, stored, treated and used in equipment, or in a process, using oil, coal, gas, biomass or electricity. Energy end-uses include heating, cooling, production processes, transport, pumping etc. The major industrial sectors in terms of energy consumption are shown in Figure 3.3 below:

**Figure 3.3 Industrial Energy Use by Sector, 2004**




Source: UNEP (2016)

*Case Study: EE Technologies in the Iron and Steel Sector*

The iron and steel industry is the largest industrial energy consumer and share of energy as a proportion of total cost is high, up to 40% of the cost of manufacturing steel (UNEP, 2016). Some processes that steel manufacturers currently employ to increase energy efficiency include- enhancing continuous production processes to reduce heat loss, recover waste energy, design efficient electric arc furnaces, and carry out “near-net-shape casting”, which is the production of items close to their final shape, rather than ingots that need to be rolled and pressed as an additional energy-intensive step. Some specific measures and technologies at different stages of iron and steel making to improve energy efficiency are in Table 3.4 below.

**Table 3.4 Opportunities in Iron and Steel Sector for Energy Efficiency Improvement**

| **Sub-Sector/Product** | **Energy efficiency opportunities** | |
|---|---|---|
| **Iron making - blast furnace** | Injection of pulverised coal<br>Injection of natural gas<br>Injection of oil<br>Injection of plastic waste<br>Injection of coke oven gas and basic oxygen furnace gas<br>Charging carbon composite agglomerates<br>Top pressure recovery turbines | Recovery of blast furnace gas<br>Top gas recycling<br>Improved blast furnace control<br>Slag heat recovery<br>Pre-heating of fuel for hot stove<br>Improvement of combustion in hot stove<br>Improved hot stove control |
| **Steelmaking - Basic oxide furnace** | Recovery of Basic Oxygen Furnace (BOF)[8] gas and sensible heat<br>Variable speed drive on ventilation fans<br>Ladle pre-heating | Improvement of process monitoring and control<br>Efficient ladle heating program |
| **Steelmaking – Electric Arc Furnace (EAF)** | Variable speed drives<br>Oxy-fuel burners / lancing<br>Post combustion of flue gasses<br>Improving process control<br>Direct current are furnace | Scrap pre-heating<br>Visage injection<br>Air tight operation<br>Bottom stirring / gas injection |
| **Casting and refining** | Integration of casting and rolling<br>Lade pre-heating<br>Tundish heating | |
| **Metal shaping** | Use efficient drive units<br>Gate communicated turn off inverters<br>Installation of automated lubrication system | |

| | | |
|---|---|---|
| **Hot rolling** | Recuperative or regenerative burners<br>Flameless burners<br>Controlling oxygen levels<br>Variable speed drives on combustion air fans<br>Hot charging | Integration of casting and rolling<br>Proper reheating temperature<br>Process control in hot strip mill<br>Heat recovery to the product<br>Waste heat recovery from cooling water |
| **Cold rolling** | Continuous annealing<br>Reducing losses on annealing line | Reduced steam use in the acid pickling line<br>Inter-electrode insulation in electrolytic picking line |

Source: UNEP (2016)

### iii. Transport

Electric vehicles (EVs) represent one of the most promising technology pathways for reducing oil use and $CO_2$ emissions on a per-kilometer basis. With a moderately clean electric grid, EVs can achieve emissions of 50 grams of $CO_2$ per kilometer (IEA, 2010). EVs can also be an independent distributed energy source for the electricity grid.

[8] The gas produced in the BOF has a temperature of approximately 1200°C. The gas is produced intermittently, its composition can vary hence many steel plants flare the gas. However, by recovering sensible and latent heat, this process can become a net energy generator (IEA, 2007).
Latent and sensible heat are types of energy released. **Latent heat** is related to changes in phase between liquids, gases, and solids. **Sensible heat** is related to changes in temperature of a gas or object with no change in phase (NCSU, 2013).

*Case Study: Vehicle To Grid Charging Infrastructure*

Electric-drive vehicles generate the energy and power electronics to produce 60-Hz AC electricity, which can be used to power residences and offices. When this electricity flows from cars to power lines, it is referred to as “vehicle-to-grid” (V2G) power. V2G technology promotes clean and efficient energy powered transportation, by allowing electric vehicles to power and be powered by the grid ( (Tugrul U. Daim, 2016)

A pilot project was conducted in the UK in 2016 to charge electric cars at times when energy costs are low and release energy back into the grid when demand peaked, with a reasonable economic return. Integrated energy company Enel and Japanese car manufacturer Nissan conducted the project. These companies collaborated to develop an energy management solution with a V2G recharging device that allows car owners as well as energy users to operate as individual “energy hubs”, that are able to draw, store and return electricity to the grid. As a part of the pilot, 100 V2G units were installed and connected at locations agreed by private and fleet owners of Nissan Leaf and e-NV200 electric vans. This project, if scaled up, is expected to help the grid strengthen its ability to handle distributed renewable energy, increasing the spread of renewable energy and reducing the cost (ENEL, 2016).

## iv. Power Sector

### *1. Distributed Generation*

When power is generated on site, rather than at a central location, it reduces the cost, complexity and inefficiency of transmission and distribution. District heating and district cooling are systems that carry out distributed generation of space heating, space cooling or hot water. When buildings in an area are connected to a district heating or cooling system, they do not require individual boilers or chillers. Renewable or other energy sources can be used in this system and the system can result in energy savings ranging from 25 to 50%, depending on system characteristics[9]. Specifically, the advantages of a district cooling system include:

- Cost savings due to benefits of scale
- Increase in efficiency due to reduced urban heat island effect from many split and window air conditioners
- Environmental benefits due to the use of a variety of energy sources, including renewable energy and waste heat, lower use of harmful refrigerants and pollutants
- Improved comfort and reliability within the buildings

However, developing district cooling faces challenges including gaining customer acceptance, higher upfront investment, high cost of land for centralized cooling system and requirement of coordination among several market participants.

[9] The efficiency gains from a district heating or cooling system can vary greatly, depending on factors such as climatic conditions affecting demand for heating/ cooling, heat/ cooling loss due to uninsulated buildings, whether waste heat is used etc.

*Case Study: Potential for District Cooling in China*

North America, Middle East, Europe, and Japan account for over 80% of the global district cooling market. China's district cooling at present is approximately 5.9 TWh and is expected to increase rapidly, at the rate of 5.39 TWh annually, enabling it to match the size of the North American market for district cooling by 2022 (ADB, 2017).

The district cooling market in China accelerated in the 11th 5-year plan period (2006-10) and currently most tier I and II cities in China have some district cooling systems, primarily for commercial and industrial complexes. Several district cooling plants in China rely on trigeneration- combined cooling heat and power plants. Table 3.5 contains a snapshot of some district cooling plants in China from 2001 onwards.

**Table 3.5 Snapshot of China District Cooling Projects**

| Project Name | Project Overview | Status |
|---|---|---|
| **Shanghai Pudong International Airport** | Inception year: 2001<br>Project owner: Shanghai International Airport Co., Ltd.<br>Type of owner: State-owned Enterprise<br>Total cooling load: 170 MW<br>Total cooling area: 1.07 million m2<br>Technology: CCHP<br>Cooling technology: Electric compressor chillers and absorption chillers | Implemented |
| **Sanya Yalongwan** | Inception year: 2011<br>Project owner: Huade Pengye Energy Investment Co., Ltd.<br>Type of owner: Energy investor<br>Total cooling load: 31.24 MW<br>Total cooling area: 0.36 million m2<br>Overall technology: Pure cooling<br>Cooling technology: Electric chillers (23.7 MW) combined with ice storage<br>Temperature: 3.3°/11° (supply/return) | The first-stage project (8 of 11 hotels) has been implemented |
| **Shenzheng Qianhai** | Inception year: 2015<br>Project owner: Shenzhen Qianhai Energy Investment Co., Ltd<br>Type of owner: Energy investor<br>Total cooling load: 1,406 MW<br>Total cooling area: 27 million m2<br>Overall technology: Pure cooling<br>Cooling technology: Electric chillers combined with ice storage | Ongoing |

Source: ADB (2017)

Currently, China does not have specific regulations, policies or government guidelines on district cooling or heating and the existing systems are mainly market driven. Business models for district cooling include:

- An electricity or gas utility invests in district cooling, owns the assets, manages them and provides district cooling to customers
- Private firms and utilities act as co-investors
- Private investors partner with utilities, the utility only provides the service. The utility may work under an energy saving contract.
- Real estate developers provide district cooling, in partnership with electricity and gas utilities and the municipal government.

District cooling utilities in China are owned by private investors, asset managers, energy services company (ESCOs) and comprise both domestic and international firms (ADB, 2017).

### *2. Smart Grids*

A smart grid consists of four layers: hardware such as advanced metering and sensors; two-way communications between utility and consumer, analytical software to process the data and IT-enabled operational processes. A smart grid can offer substantial energy efficiency gains by allowing consumers to better understand their energy use by using smart meters which help utilities operate the grid more efficiently and reliably by analyzing second-by-second demand data. Utilities can also reduce congestion during peak periods through demand response programs and encouraging charging of plug-in electric vehicles during off-peak hours.

*Case Study: Utilities, Smart Meters and Big Data*

As the use of sensors, network communication and cloud computing rises, utilities, firms and EE service providers are increasingly gathering large amounts of energy data. This data can be used for power generation side management, microgrid and renewable energy management, asset management and collaborative operation, and demand side management (Kaile Zhou, 2016).

Utilities are moving from a single meter reading in a month to smart meter readings every 15 minutes, which means a 3000-fold increase in data. The data gathered from smart meters can be used to analyze consumer stratification, behavior patterns and how pricing influences usage. Big data can be used for granular forecasting and load planning, improving the efficiency of generation and scheduling (IBM, 2012).

Oncor, a private utility in Texas installed over a million smart meters to access real time energy usage. It provided this data to its consumers in real time, allowing them to see how they consume energy and make changes to it. This resulted in energy savings of 5-10%. Additionally, they installed sensors across their distribution network, to track and quickly respond to power outages (IBM, 2013).

# 4. DEMAND DRIVERS AND OPPORTUNITIES FOR EE SERVICES

This section covers the demand drivers for EE services- including policies, economic environment and social and environmental factors. This is followed by a discussion of the opportunities facing the EE services sector in APEC.

## A. DEMAND DRIVERS FOR EE SERVICES

The global ESP market is experiencing growth across the world, with only ESCOs (not including other ESPs) valued at more than USD 24 billion in 2015 (IEA, 2016). Factors that are driving demand for EE services across economies, include the policy environment, economics, technology and social and environmental drivers.

### i. Policy and Regulatory Environment

1. An economy's **energy efficiency target** is a major driver for its public and private sector to implement energy efficiency, giving a boost to the EE services industry. For example, China set binding domestic targets for energy conservation and emissions reduction in the $11^{th}$ (2006- 2010) and $12^{th}$ ( 2011-2015) Five Year Plans. In the $12^{th}$ Five Year Plan, energy intensity of the economy was set a target of reducing by approximately 16% compared to 2010. The target was disaggregated to the province level, and large energy consumers were the focus of local governments to achieve targets (IFC, 2012). These efforts built on the successful Top-1,000 Program, which focused on the economy's top 1,000 energy-consuming enterprises. Because of this initiative, China cut its energy intensity by almost 20 percent between 2006 and 2010 - primarily through energy efficiency upgrades and by closing obsolete facilities (ADB, 2013).

   All APEC economies now have some form of energy efficiency target in place. Table 4.1 below highlights the main targets set by Governments in APEC economies and the expected investment required to meet these targets.

**Table 4.1 APEC EE Targets for 2020**

| Economy | Energy Efficiency Targets, 2020 | Required Investment, USD million |
|---|---|---|
| **Brunei Darussalam** | Attain 25% reduction of energy intensity from 2005 level by 2030 | 48 |
| **Indonesia** | Decrease energy intensity by 1% annually and decrease energy-GDP elasticity to below 1% by 2025 | 6 |
| **Malaysia** | Reduce final energy consumption in the industry, commercial and residential sectors by 10% from 2011 to 2030, and reduce final energy consumption of the transport sector by 1.4 ktoe by 2030 | 901 |
| **The Philippines** | Reduce final energy consumption by 10% in all sectors from 2007 to 2014 | 601 |
| **Singapore** | Reduce energy intensity by 20% by 2020 and by 35% by 2030 from 2005 level | 97 |
| **Thailand** | Reduce the energy intensity of GDP by 25% by 2030 relative to Business as Usual (BAU) | 2,006 |
| **Viet Nam** | Reduce energy consumption by 3%-5% by 2010 and by 5%-8% by 2010-2015 | 649 |
| **China** | Reduce $CO_2$ emissions per unit of GDP by 40%-45% from 2005 level by 2020 | 865,260 |

Source: ADB (2013)

2. ESP Funds
   Creating specific funds for the EE Services sector is another driver that has promoted demand in APEC economies. Funds designed to promote a domestic ESCO industry have been used to support a sector at the nascent stage.

*Case Study: Thailand ESCO Fund*

**Thailand's** Department of Alternative Energy Development and Efficiency (DEDE) created an ESCO fund scheme in 2008 to target potential investors for small projects in energy efficiency improvement and renewable energy development, mostly to be implemented by small and medium enterprises.

The Energy for Environment Foundation (E for E) is currently designated to manage a portion of the ESCO Venture Capital fund, while another portion is entrusted to the Energy Conservation Foundation of Thailand. As of beginning of 2017, the results of ESCO fund shows that promotion of energy conservation by ESCO mechanism has resulted in energy savings of more than 3,338 million baht or 53.29 ktoe[10]. The fund contains the following sub programs:

1. Equity Investment- The ESCO Fund will make equity investments in energy efficiency or renewable energy projects. Investment criteria applied are: i) size of equity investment: 10-50 percent of total investment cost but limited to THB 50 million (USD 1.5 million) per project; ii) investment period of 5-7 years; and iii) exit method of selling back the shares to the entrepreneur, or find new strategic partners.
2. ESCO Venture Capital- The scheme will partner with ESCOs to raise capital for investments in energy saving projects. Investment criteria applied are: i) size of equity investment is 30 percent of registered capital but limited to THB 50 million (USD 1.5 million) per project; ii) investment period of 5-7 years; iii) exit method of selling back the shares to the entrepreneur, or find new strategic partners and; iv) board seat is required in the company.

3. Equipment Leasing- The leasing criteria include: i) 100 percent of equipment cost but limited to THB 10 million (USD 300,000) per project; ii) repayment duration of 5 years; and iii) interest rate of 4% per annum.

4. Carbon Credit Facility- The ESCO Fund will support project owners in developing CDM documents and help to bundle small projects so that buyers are willing to purchase the carbon credits from the projects.

5. Credit Guarantee Facility- The Fund will cooperate with financial institutions or credit guarantee agencies to assist entrepreneurs in accessing long-term loans from banks by providing a credit guarantee depending on the project risk and limited to THB 10 million (USD 300,000) at a low premium rate.

6. Technical Assistance- The ESCO fund will provide financial support for technical assistance, e.g. energy audit, feasibility study. The support is limited to THB 100,000 per project and this support must be reimbursed to the ESCO Fund unless the proposed technical solutions have been implemented.

Source: UNEP (2012)

[10] Thai ESCO Association (http://thaiesco.org/2016/thai/activitydetail.aspx?id=85).

3. Tax incentives
   Taxes and other fiscal benefits are the most common measure used by governments to promote the energy efficiency improvements in an economy. Many APEC economies already have policies and measures in place to promote the EE businesses, although their effectiveness differs considerably and most are still evolving. There are considerable variations between the incentive policies and measures employed throughout APEC. Differences are apparent between developed and transition economies, Asian, Australasian and North American economies, industrialized and agrarian economies.

*Case Study: Thailand's tax incentives for ESPs, manufacturers and consumers*

Since 2006, Thailand has put in place the following policies to promote EE:

- For ESPs[11]: Tax exemption on import duty of efficient equipment
- For ESPs and EE equipment manufacturers: Corporate tax exemption for 8 years
- For consumers: Lower corporate income tax for companies enhancing EE

(IEPD, 2016)

The incentives are monitored by the Department of Alternative Energy Development and Efficiency (DEDE) under the Ministry of Energy. The tax incentives can be availed in the following ways, listed in Table 4.2:

**Table 4.2 Options for Seeking Benefits, Thailand**

| Type of Exemption sought | Conditions | Benefits |
|---|---|---|
| **Cost-based** | Up to 50 million THB (1.5 million USD) | Corporate tax deduction phased over 5 years, i.e. 25% tax break on investment in EE |
| **Performance-based** | Up to 2 million THB (60,000 USD)<br>Performance to be audited | 30% of savings value is deductible for project owners |
| **Board of Investment** | Applicable to ESPs, EE equipment manufacturers<br>ESPs must be approved by Ministry of Energy before submitting an application | Waiver on income and import tax for 8 years |

Source: IEPD (2016)

4. Other policies
   Other government efforts include legislation (EE Acts, statutory standards and labelling), demonstration projects or strategic support to the sector. Policy approaches vary, reflecting different drivers across regions, economic and energy contexts, such as concerns over energy imports and climate change in developed APEC economies and focus on energy security and economic development among APEC economies in Southeast Asia.

The government agencies responsible for the promotion of the ESP industry in selected APEC

[11] Only ESPs using performance contracting are eligible for the tax exemption.

economies are below:

- China: National Development and Reform Commission (NDRC)
- Indonesia: Ministry of Energy and Mineral Resources (KESDM)
- Japan: Ministry of Economy, Trade and Industry (METI)
- Korea: Korean Energy Management Corporation (KEMCO)
- Malaysia: Ministry of Energy, Ministry of Finance
- The Philippines: Department of Energy (DOE)
- Singapore: National Environment Agency (NEA)
- Thailand: Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy
- United States: Department of Energy (DOE)

In a number of APEC economies, ESP associations are created and successfully cooperate with dedicated government agencies. A list of ESP associations is provided in Appendix II.

Basic energy conservation legislation has been carried out in many economies at different times such as China's Energy Conservation Law, Japan's Energy Conservation Law, Malaysia's Efficient Management of Electrical Energy Regulations, and Thailand's Energy Conservation Promotion Act. Energy-saving standards have been established based on the development of these laws. Most of them closely relate to the business growth of ESCO industry.

In the **United States**, related laws on energy conservation such as The Energy Policy and Conservation Act of 1975 (EPCA), National Energy Conservation Policy Act of 1978 (NECPA), and The Energy Policy Act of 1992 (EPAct) were implemented, and Executive Order 13123, 1999 was used to promote public facilities which is the main market in the United States. An Executive Order issued in 2012 helps meet the national goal of deploying 40 gigawatts of new, cost-effective industrial combined heat and power (CHP) by the end of 2020. CHP involves recovering the heat normally lost in power generation and using it to provide useful thermal energy to businesses and factories. If achieved, this goal will help generate significant amount of electricity over their entire lifetime (White House, 2012).

A successful mix of information provision and regulation has played a leading role in stimulating the energy efficiency market in **Japan**. Measures developed include: standards and labelling for a range of products (including light-duty vehicles, new buildings, appliances, lighting and other equipment used in the commercial and industrial sectors); providing access to energy assessments and to preferential financing; and energy efficiency obligations placed on energy suppliers. Assessments of these programs show that most have had a positive impact on the size of national energy efficiency markets.

*Case Study: South Korea's mix of Policy and Financial Support*

The South Korean government helped the nascent EE service industry through measures such as

- Retooling its Energy Act in order to financially support ESCOs
- Providing tax credits for ESCO projects
- Grating long term, low interest loans to ESCO projects
- Providing loans through Korea Energy Management Corporation (KEMCO) using surcharges on import and/or sale of oil and some petroleum products

However, studies have shown that despite receiving financial support, the ESCO industry of Korea grew only after institutional barriers (Government procurement procedures, budgeting, accounting laws to allow multi-year contracts) were removed in 1998 (Ellis, 2010).

### ii. Economic Drivers

**Energy prices** are one of the key factors driving expansion of the energy efficiency market in APEC economies. Historically, sustained high energy prices have triggered energy-saving activity. Over the past decade, increases in global oil prices have stimulated technological innovation and enhanced efficiency in various sectors within most APEC member economies, which will continue to deliver energy savings in coming years. These high prices have also created the political space to develop and implement policies that reduce market barriers that impede energy efficiency investments. Energy prices and the presence (or absence) of transparent and dynamic price signals can facilitate or hinder investment in energy efficiency. For example, various fossil fuel subsidies distort price signals, lowering the demand for energy efficiency by artificially reducing the price consumers pay for energy. However, other barriers to energy efficiency mean that transparent pricing alone does not directly lead to an optimal level of energy efficiency investment.

### iii. Technology Drivers

Rapid advancements in technology (described in Section 3.1 Technology Trends in EE) are leading to a rise in demand for EE services, as energy end-users lack the expertise to identify appropriate energy saving technologies, estimate savings and assess costs and benefits. This is particularly true for public institutions such as hospitals and schools (IFC, 2012). The process followed by ESPs described in Table 4.3 shows the technical, financial and other skills that are required to successfully implement an EE project.

**Table 4.3 ESP Activities and Expertise**

| ESP Activity | Activity Description | Expertise |
|---|---|---|
| Initial assessment | Walk-through audit of the facility to determine scope and size of the project | Business Development, |
| Investment Grade Energy Audit (IGA) | Analyze all cost-effective EE measures (EEMs) for lighting, HVAC, building envelope, process energy, waste management systems etc. The IGA will evaluate the economic performance and investment value of EEMs identified. | Technical |
| Cost Effectiveness Criteria | A project is considered cost effective, if it leads to a positive Net Present Value over its lifetime. | Financial |
| Performance Contract (optional) | If required, the ESCO and consumer sign an Energy Savings Performance Contract and an independent agency sets the baseline and measures and verifies energy savings achieved after implementation. | Legal, Risk Management |
| Project Implementation | Construction, installation as required | Project Management, Construction |

Source: WSDES (2012)

### iv. Social and Environmental Drivers

While social and environmental norms are not as powerful as regulatory or economic factors, they do play a role in promoting energy efficiency. Larger companies in developed economies require the services of ESCOs to ensure that their supply chain is energy efficient and has a small carbon footprint, which is then reported as a part of the company's Corporate Social Responsibility (CSR). Research has shown that in developing economies with weak regulatory enforcement, voluntary activities to save energy occur through companies' CSR activities. The research suggests that further investment by companies in EE can occur if CSR activities are incentivised (Shiro Horia, 2014).

## B. OPPORTUNITIES FOR EE SERVICE BUSINESSES IN APEC

Total final energy demand in APEC is expected to reach 7,000 million tons of oil equivalent (Mtoe) in 2040, rising 32% compared with 2013 levels, with China and South-East Asia being the main drivers of growth (APEC, 2016).

By region, the **United States; and Canada** have the most developed ESP markets. In the US, the greatest market penetration is in schools, Government buildings and hospitals. There are numerous opportunities in commercial buildings and SMEs that can be explored. ESP markets in **China; Thailand; and Korea** have been expanding since 2011. In China, there has been a 14% growth in the number of employees in the ESP industry, standing at over 400,000 in 2012. **Malaysia; the Philippines; and Viet Nam** have a small number of ESP firms, suggesting that a large market lies untapped. **Chile** has among the highest energy prices in South America and access to renewable energy, providing an incentive for ESPs to work in partnership with renewable energy providers. Australia has seen a rising demand for EE services in buildings, stimulated by the government's certification and rating schemes (European Commission, 2014).

Based on the demand and technology trends discussed in the section above, Table 4.4 summarises the opportunities for ESPs in APEC by sector.

**Table 4.4 Opportunities for ESPs in APEC by Sector and Technology**

| **Sectors** | **Energy demand, 2013** | **Policy Drivers** | **Technologies** | **Opportunities for ESPs** |
|---|---|---|---|---|
| Buildings | 31% | Minimum Energy Performance Standards (MEPS)<br>Building Codes | Insulation HVAC improvements<br>IoT | Opportunities in growing commercial sector- e.g. BPOs in the Philippines |
| Industry | 33% | Mandatory energy auditing (Australia)<br>Requirement for large units to have energy managers, | Minimising heat losses<br>Heat recovery through exchangers<br>Right sizing motors | Less energy intensive sectors such as construction, electronics and food products |
| Transport | 26% | Subsidies for new technologies (Japan) Green vehicle subsidy and tax on high consumption vehicles (United States; and Hong Kong, China ) | Improving fuel efficiency | Opportunities to partner with utilities for smart charging, V2G |
| Power | ---[12] | Creating energy districts (Russia; and Hong Kong, China) | District heating and cooling, smart grid | Act as district cooling utility |

Source: APEC (2016), APERC (2016)

[12] Energy demand in the power sector is part of the industrial sector.

# 5. CONCLUSION

APEC economies are increasing their energy use to meet population growth and rising standards of living. APEC economies have set a target of decreasing the energy intensity by 45% from 2005 to 2035 (APEC, 2013). In order to meet this target, the use of energy efficiency products and services needs to register sharp growth. Some economies in APEC are a manufacturing hub for EE products (lights, ACs, other appliances), while others have a robust ESP sector that carries out activities such as Investment Grade Audits, building retrofits using a performance contracting or consultancy model. The aim of this report is to highlight the trends in demand and technology for EE services, note the existing policy framework and lay out challenges and opportunities for the sector in APEC. To summarize:

Key trends in EE technology:

- Efficient building materials
- Reducing energy consumption of IoT- connected appliances
- Industry-specific efficiency technologies
- Vehicle To Grid
- Distributed Power Generation

Key drivers for EE in APEC economies:

- National policies and priorities on energy intensity
- Structural factors such as share of industrial sector in economy, innovation, supply chain
- Energy efficiency infrastructure including prevalence of energy management system, presence of ESPs and EE equipment manufacturing firms
- Availability of finance for efficiency improvements to end-users and ESPs

EE Services cover a variety of business models, from consulting to performance contracting. Across economies, they are a part of different industries, under UN CPC 94, including

- 1710 - Electrical Energy
- 512 - Construction work for buildings
- 513 - Construction work for civil engineering
- 514 - Assembly and erection of prefabricated constructions
- 516 - Installation work
- 517 - Building completion and finishing work
- 811 - Financial intermediation services, except insurance and pension fund services
- 831 - Leasing or rental services concerning machinery and equipment without operator
- 867 - Architectural, engineering and other technical services
- 879 - Other business services
- 94090 - Other environmental protection services

APEC officials have endorsed the Environmental Services Action Plan (ESAP) in the September 2015 meeting in Cebu, the Philippines. In November 2016, APEC published its

Survey of Regulatory Measures in Environmental Services, covering the following environmental services under UN CPC 94:

- 941 - Sewerage, sewage treatment and septic tank cleaning services
- 942 - Waste collection services
- 943 - Waste treatment and disposal services
- 944 - Remediation services
- 945 - Sanitation and similar services
- 949 - Other environmental protection services

This report on EE services in APEC marks the first step to consider and study a wider range of environmental services beyond CPC 94, as a part of “Other Environmental Service”.

# APPENDIX I: MAJOR EE MARKET PLAYERS IN APEC

## Thailand

| Company | Description |
|---|---|
| Energy Design Concept | Services provided: technology and equipment and consultancy.<br>Authorised capital 55 million baht.<br>Technology tie ups with Electrolux, Optilux |
| Energy Conservation Systems Thailand | Services provided: technology and equipment, installation, maintenance and equipment servicing, consultancy<br>Authorised capital: 50 million baht<br>Technology tie ups with Broad, Altivar, Powerlogic |
| Elyo/ Cofely | Services provided: technology and equipment, installation, maintenance and equipment servicing, consultancy<br>Authorised capital: 50 million baht<br>Technology tie ups with Sullair, Carrier, Kaeser, Atlas Copco, Hiross |
| BTM Engineering | Services provided: installation, maintenance and equipment servicing<br>Authorised capital: 20 million baht<br>Technology tie ups with Trane, York, Hitachi |
| Guarantee Company Engineering | Services provided: technology and equipment, installation, maintenance and equipment servicing, consultancy<br>Authorised capital: 50 million baht<br>Focus on industrial and commercial sector |
| Excellent Energy International | Services provided: technology and equipment<br>Authorised capital: 25 million baht<br>Technology tie ups with Carrier, ECM |
| Chamnankankij Engineering | Services provided: installation, maintenance and equipment servicing<br>Authorised capital: 20 million baht |
| Attain Engineering and Energy | Services provided installation, maintenance and equipment servicing<br>Authorised capital: 10 million baht<br>Technology tie ups with EMK, KEB Inverters |
| Energica | Services provided:installation, maintenance and equipment servicing<br>Authorised capital: 10 million baht<br>Technology tie ups with Man Gas Engines, Tethys Instruments |

Source: Thai ESCO (2011)

**United States**

| **Company** | **Description** |
|---|---|
| ABM Industries | Leading provider of end-to-end facility solutions with revenues of approximately $5.0 billion. |
| AECOM<br>McKinstry<br>Metrus Energy<br>Ameresco | Provider of advisory and infrastructure asses for governments, businesses and organizations. Develops and finances large-scale energy efficiency projects |
| Energy Systems Group | Leading energy services provider that specializes in energy efficiency, sustainability, and infrastructure improvement solutions. |
| Siemens Industry<br>Schneider Electric<br>Johnson Controls | Leading provider of energy and environmental solutions, building controls, fire safety and security systems solutions. |
| AMERESCO<br>ConEdison Solution | Leading independent provider of energy efficiency, infrastructure upgrades, asset sustainability and renewable energy solutions. |
| Honeywell International<br>SCIenergy | Leader in the Internet of Things (IoT) and creates products, software and technologies for building management solutions |

**Australia**

| Company | Description |
|---|---|
| Siemens | Leading provider of energy and environmental solutions |
| AECOM | Provider of advisory and infrastructure asses for governments, businesses and organizations |
| Energetics | specialist management consultancy providing energy and carbon advisory services |
| Phillips | Provider of energy efficient solutions and technologies |
| AGL | Leading integrated energy companies providing electricity, gas, solar & renewable energy services |
| Energy Action | Leading provider of innovative Energy Procurement, Contract Management & Environmental Reporting, and Projects and Advisory Services |
| Schneider Electric | Energy management and automation service provider |
| AE Smith | Technical and engineering services provider |
| ENGIE Services ANZ | Service provider of building solutions |
| Total Energy Solutions | Energy and water efficiency solution provider |
| Ecosave | Energy efficiency retrofit service provider with guaranteed savings |
| ERM Business Energy | Technical and engineering services provider |

**China**

| **Company** | **Description** |
| --- | --- |
| Shaangu Energy Saving & Service Company | SPC is a professional company who provides systematic solutions in energy recovery and power generation. |
| Beijing PowerU | Provider of chilled water cool storage technologies that save energy. |
| Beijing Shenwu Environment & Energy Technology | solution provider for energy conservation and environmental protection technology with registered capital of RMB 360 million Yuan, |
| China Energy Conservation and Environmental Protection | China Energy Conservation and Environmental Protection Group (CECEP) is the largest service-oriented scientific industrial group in the energy conservation and environmental protection field in China. |
| Beijing Kingtech Co. Ltd | Energy saving solutions in industrial applications |
| Schneider Electrics | Provider of solutions for energy and infrastructure, industrial processes, building automation, and data centers/networks, |
| Beijing Tellhow Intelligent Engineering Co. | Provider of energy saving solutions |

# APPENDIX II: ESP ASSOCIATIONS IN APEC

| **Economy** | **ESCO Association** |
|---|---|
| Australia | Australasian Energy Performance Contracting Association (AEPCA) |
| Canada | Energy Services Association of Canada |
| Chile | National Association of Energy Efficiency Companies Chile (ANESCO Chile) |
| China | China Energy Management Company Association (EMCA) |
| Hong Kong, China | Hong Kong Association of Energy Service Companies (HAESCO) |
| Indonesia | Indonesia ESCO Association |
| Japan | Japan Association of Energy Service Companies (JAESCO) |
| Korea | Korean Association of ESCO Companies (KAESCO) |
| Malaysia | Malaysia Association of Energy Service Companies (MAESA) |
| Mexico | Mexican Association of Companies ESCO (AMESCO) |
| The Philippines | ESCO Association of the Philippines (ESCO Phil) |
| United States | National Association of Energy Efficiency Companies (NAESCO) |

Source: European Commission (2014)

# APPENDIX III. MAJOR MANUFACTURERS OF EE EQUIPMENT IN APEC ECONOMIES

| APEC Economies | Lighting | HVAC (Market share) | Building Management Systems |
|---|---|---|---|
| **Thailand** | Asia Lamp Industry Company Limited[13]; L&E[14]; Panasonic; Phillips; Osram; GE; Racer Electric Thailand Co., Ltd.[15] | Mitsubishi (34%); LG (19%); Panasonic (17%); Others (30)[16]; | Cisco; Honeywell; Johnson Controls; Schneider Electric; United Technologies |
| **The Philippines** | Philips; GE; OSRAM; Omni; Firefly; Akari, Toshiba; Starlux; Econowatt[17]; | Concepcion (53%); Panasonic (20%); Fedders (12%); Other (15%)[18]; | |
| **China** | Philips; General Electric and Osram; NVC; TCL; Foshan Lighting; Yankon Energetic Lighting and Opple; | Chigo; Midea; Gree; Changhong; TCL and Hisense; | |
| **United States** | Philips; GE; OSRAM | Carrier (17%); Daikin (15%); Trane (10%); York (9%); (Statista, 2017) | |
| **Viet Nam** | Rang Dong; Dien Quang; Phillips; | Panasonic (26.7%); Daikin (21.6%)[19]; | |
| **Malaysia** | | LG; Panasonic and York; 20 % manufactured locally[20]; | |
| **Singapore** | | Daikin and Mitsubishi (60%); Panasonic; | |

[13] Asia Lamp Industry Company Limited – also original equipment manufacturer (OEM) for other brands
[14] Lighting & Equipment Public Company Limited - L&E – also original equipment manufacturer (OEM) for other brands
[15] Racer Electric Thailand Co., Ltd. - also original equipment manufacturer (OEM) for other brands
[16] Marketeer, 2016
[17] All lighting products sold in the Philippines are mainly imported from China; India; and Viet Nam.
Information source: IIEC Retail survey (2015)
[18] The ASEAN SHINE program
[19] Manufacturers survey conducted by the International Copper Association
[20] ASEAN Shine

| APEC Economies | Lighting | HVAC (Market share) | Building Management Systems |
|---|---|---|---|
| | | Fujitsu General; Mhi; (Jarn, 2013) | |
| **Korea** | | LG and Samsung (80%) (Jarn, year) | |
| **Indonesia** | Philips; Panasonic; Osram; Ge; Toshiba; Sylvania; Indomaret; Shukaku; Cosmos[21]; | | |

[21] 80% imported from China. (Manoppo, J. (2016). Fact & Figures: Lighting in Indonesia Today. Jakarta: Asosiasi Industri Perlampuan Listrik Indonesia (APERLINDO - Indonesian Electrical Lighting Industry Association)

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# ABBREVIATIONS

| | |
|---|---|
| ACEEE | American Council for an Energy Efficient Economy |
| APEC | Asia-Pacific Economic Cooperation Secretariat |
| ASEAN | Association of Southeast Asian Nations |
| BBEE | Behavior Based Energy Efficiency |
| BEE | Bureau of Energy Efficiency |
| BOF | Basic Oxygen Furnace |
| BRESL | Barrier Removal to the cost-effective development of Energy Efficiency Standards and Labelling |
| BTU | British Thermal Units |
| CCHP | Combined Cooling Heating And Power |
| CHP | Combined Heat and Power |
| CER | Certified Emissions Reduction |
| CLASP | Collaborative Labeling and Appliance Standards Program |
| CPC | Central Product Classification |
| DEDE | Department of Alternative Energy Development and Efficiency |
| DoE | Department of Energy |
| EAF | Electric Arc Furnace |
| EBRD | European Bank for Reconstruction and Development |
| EE | Energy Efficiency |
| ESCO | Energy Service Company |
| ESP | Energy Service Provider |
| ESPC | Energy Savings Performance Contracting |
| EV | Electric Vehicle |
| GHG | Greenhouse Gas |
| HVAC | Heating Ventilation Air Conditioning |
| IEA | International Energy Agency |
| IGA | Investment Grade Audit |
| IoT | Internet of Things |
| KEMCO | Korean Energy Management Corporation |
| KESDM | Indonesia: Ministry of Energy and Mineral Resources |
| LBNL | Lawrence Berkeley National Laboratory |
| LED | Light Emitting Diode |
| METI | Ministry of Economy, Trade and Industry |
| MToE | Million Tons of Oil equivalent |
| NDRC | National Development and Reform Commission |
| NZEB | Nearly Net Zero Energy Building |
| OLED | Organic Light-Emitting Diode |
| PV | Photo Voltaic |
| SEAD | Super-Efficient Equipment and Appliance Deployment |
| SEI | Sustainable Energy Initiative |
| TCE | Tons Of Coal Equivalent |
| THB | Thailand Baht |
| TFED | Total Final Energy Demand |
| TWh | Tera Watt hour |

| | |
|---|---|
| V2G | Vehicle To Grid |
| WOL | Wake-on-LAN |