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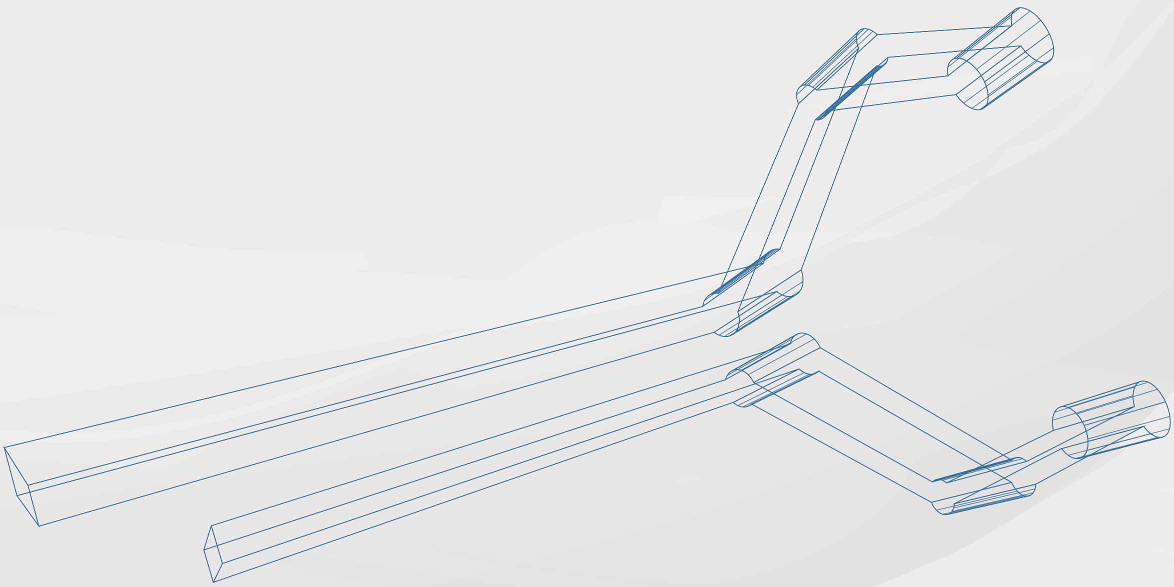
SECTORAL REPORT



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Electrical & Electronics Sector

AKADEMI SAINS MALAYSIA

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FOREWORD

These Sectoral Reports are the output of the Academy's Mega Science Studies for Sustained National Development (2013-2050), a Flagship Programme of the Academy, first introduced by my predecessor, Academician Tan Sri Dr Yusof Basiron FASc. The first series of reports covering Water, Energy, Health, Agriculture and Biodiversity have already been published.

The Academy had adopted the concept of a Mega Science Framework as a comprehensive vehicle to drive the use of Science, Technology and Innovation (STI) to contribute towards economic growth. Mega essentially means big, therefore the disciplines of Mega Science implies a pervasive (broad-based), intensive (in-depth), and extensive (long period of engagement) use of science knowledge to produce technologies, products and services for all sectors of the economy to derive economic growth and development. It also calls for extensive investment in research and development activities to enhance the knowledge base for the targeted sectors. Since knowledge in marketing and finance is equally important in promoting the success of a commercial venture as compared to technical needs, it is envisaged that the Mega Science approach will require research to be conducted both in non-technical as well as in traditional scientific sectors.

We are confident that the ideas and findings contained in this second series of Reports covering the Sectors of Housing, Infrastructure, Transportation, Electrical and Electronics, and Environment, where the science, engineering and technological areas have been identified in the short-term (2013 – 2020), medium-term (2021 – 2035) and long-term (2036 – 2050) periods, will be of use by the central agencies' policy makers and planners as well as by the other relevant Ministries.

I would like to record our appreciation to the Government of Malaysia for supporting this Study financially as part of the 10th Malaysia Plan. Continued financial support from the Government is essential for the Academy to continue with its Flagship Programmes in the other Sectors which have already been identified. I would also like to congratulate the Sectoral Team Leaders and all Fellows of the Academy who were involved in producing these Sectoral Reports for a job well done.

TAN SRI DATUK DR AHMAD TAJUDDIN ALI FASc
President
Academy of Sciences Malaysia

PREFACE

In this second series of the Mega Science Framework Studies for Sustained National Development (2013-2050), undertaken by the Academy of Sciences Malaysia, STI opportunities have been identified and roadmaps provided for the short to long term applications of Science, Engineering and Technology (SET) in the critical and overarching sectors such as housing, infrastructure, transportation, electrical and electronics, and the environment sectors. These sectors were selected on the basis of their inter-connectedness with the electrical and electronics sector providing the platform towards the "Internet of Things" and linking the four other sectors seamlessly.

One of the most frequently asked questions by decision-makers and scientists themselves is "How can STI contribute more effectively to economic development and wellness in a sustained manner without compromising the environment's sustainability". There are good reasons to refer to STI because they have a track record to meet critical challenges posed primarily by the growth of human population and their wants. In this respect, and especially in the 5 new sectors, STI will rise again to meet the new challenges in response to the national and global demand to factor towards enhancing quality of life in all products, processes, services and development projects.

The biggest challenge to all scientists is how to use the fixed earth resources (especially water, land, forests and minerals) to produce food, water and goods for human needs without depriving habitats for the millions of other species and destroying the ecosystems. Proven existing technologies must continuously be improved to be eco-friendly whilst the emerging one such as renewable energy, genomics, stem cells, nanotechnology, biotechnology and the noveau-ICT must conform to the new order of sustainability, ethical and moral obligations whilst contributing to the economic development of the nation. The environment sector has attempted to address these issues.

There are vast opportunities in various sectors of the national economy which can be leveraged upon in an attempt to resolve challenges and problems faced by the populace through innovative approaches in the application of SET. Through identifying and developing various tools through SET, it will go towards ensuring that our economy is not only sustained but sustained in a sustainable manner.

The Academy recognises the importance of cross disciplines linkages that must be integrated during planning, implementation and monitoring of national programs and projects. Social engineering must be designed to match the rapid technical advances to minimise their negative impacts, including the implementation of Life Cycle Assessments (LCA) of the various products and services in these five sectors.

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ACKNOWLEDGEMENT

THE ELECTRIC & ELECTRONICS SECTOR STUDY TEAM

The Academy of Sciences Malaysia (ASM) wishes to thank and acknowledge the following Sectoral Team Members for the provision of their expertise and technical input in the preparation of the Report as well as for ensuring that the Report was completed in a timely manner:

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EXECUTIVE SUMMARY

MEGA SCIENCE 2.0 | ELECTRIC & ELECTRONIC SECTOR

1.1 PURPOSE OF THE STUDY

The Mega Science Framework Study for Sustainable National Development undertaken by the Academy of Sciences Malaysia (ASM) has the purpose of producing a roadmap and action plans that will provide relevant insights and guidance to the Government of Malaysia, in relation to the development of Malaysia's electrical and electronics sector.

1.2 OBJECTIVES

In developing a framework for Malaysia's sustainablenational development that focuses on specific targets and desired outcomes over the short-term (2015 – 2020), medium-term (2021 – 2035) and long-term (2036 – 2050), the following are the terms of reference of the study:

1. Assessing and analysing global drivers of sustainable development and the critical role of innovation in national development. Global drivers include worldwide concern over climate change and its impact on sustainability, the shift towards a knowledge-based economy in which intangibles dominate, the growing influence of innovation on sustaining competitiveness, concern over poverty, and the fate of the environment and the Millennium Development Goals.

2. Undertaking a review and analysis of the Government's various development policies, This include as the 5-Year Development Plans, Industrial Master Plans, Outline Perspective Plans,

S&T Policies, K-Economy Master Plan, National Education Policy, National Higher Education Policy, National Agriculture Policy and so on *vis-à-vis* sustainable development.

3. Assessing and determining the economic, social, and environmental targets as outlined in the plans and policies. This is to reflect the 3 dimensions of sustainability and the multi-sectoral nature of sustainable development.

4. Addressing policies, strategies and action plans for implementation for the period from 2010 – 2050 (10th – 18th Malaysia Plans).

The scope of work of the study is as follows:

1. Setting the desired outcomes in Electrical and Electronics, benchmarking with developed countries and identifying suitable indicators and milestones which will serve as measurable targets for monitoring progress and attainment of objectives

2. Establishing Malaysia's current status

3. Undertaking case-studies of other developed countries to establish how they have employed STI in achieving their outcomes

4. Identifying the current gaps in STI knowledge and development in the Electrical and Electronics sector and how these gaps may be bridged in order to achieve the desired outcomes

5. Identifying and proposing areas in research, development and commercialisation in the Electrical and Electronics (E&E) sector where Malaysia has a competitive edge and can contribute to overall sustained economic growth of the country and to identify sources of future growth opportunities in the various areas in the Electrical and Electronics sector

6. Conducting a review on international best practices of STI Policies and Plans for sustained national development in the Electrical and Electronics sector and to review and analyse existing government policies, strategies and plans pertaining to STI in the Electrical and Electronics sector, identify gaps and advise appropriate recommendations in line with international best practices

7. Reviewing the following focus areas which have been designated STI trigger points for the Electrical and Electronics sector:

    - Compound Semiconductor
    - Energy Generation, Transmission and Distribution
    - Solar as an Efficient Renewable Energy

8. Prepare of a draft action plan to achieve said objectives, with a road-map identifying short-term (2015-2020), medium-term (2021-2035), long-term (2036-2050), as well as R&D needs for implementation of the action plan.

1.3 FOCUS AREAS

The study highlights on the following focus areas of the electrical and electronics sector:

- Compound semiconductor
- Energy generation, transmission and distribution
- Solar as an efficient renewable energy

An Executive Summary for each of the 4 focus areas is provided in **SECTION 1.6**.

1.4 THE FRAMEWORK

The overall framework of this study is shown in **Figure 1.1**. At the epicentre of the framework are the identified focus areas of Malaysia's electrical and electronics sector. For each of these specialised focus areas, a 360º environmental scan is undertaken to identify their global drivers, analysed in tandem with Malaysia's relevant capabilities. Following this, a set of short-to-long-term targets are determined along with the associated

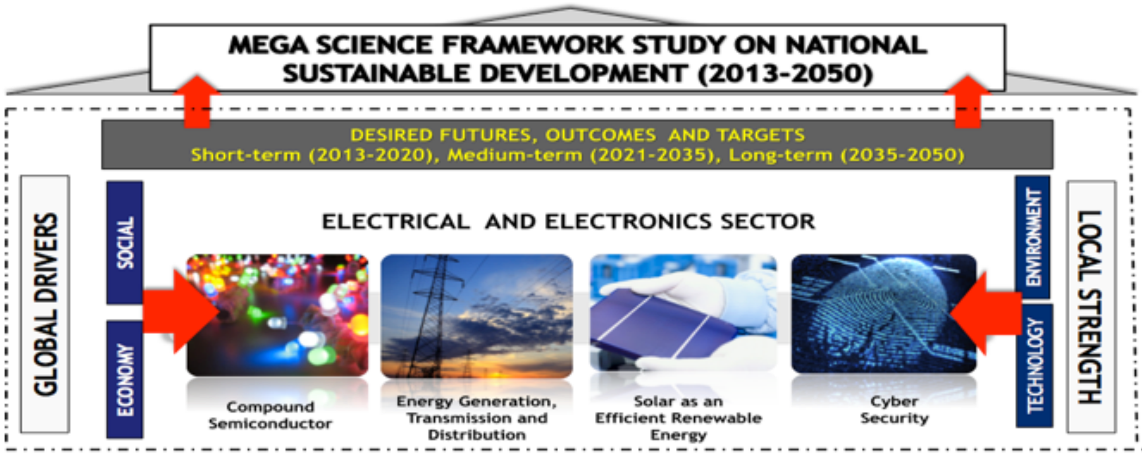

Figure 1.1 The Mega Science Framework

timelines and stakeholders. The resulting dynamic blueprint is then aligned and fine-tuned with Malaysia's various national development agenda, covering economic, regulatory and socio-environmental aspects.

1.5 METHODOLOGY

A baseline study was developed for each of the four focus areas, with the primary aim of objectively evaluating Malaysia's current status, as well as identifying growth opportunities. Using an established platform of indicator development, coupled with case studies on world-leading countries for each focus areas, a set of desired outcomes with measurable targets were then determined.

These sets of goals then form the basis for an exhaustive gap analysis, fine-tuned with stakeholder feedback from the academia, industry and authorities. A stakeholder's workshop was organised on 5th February 2014 at the ASM, for the purpose of presenting the

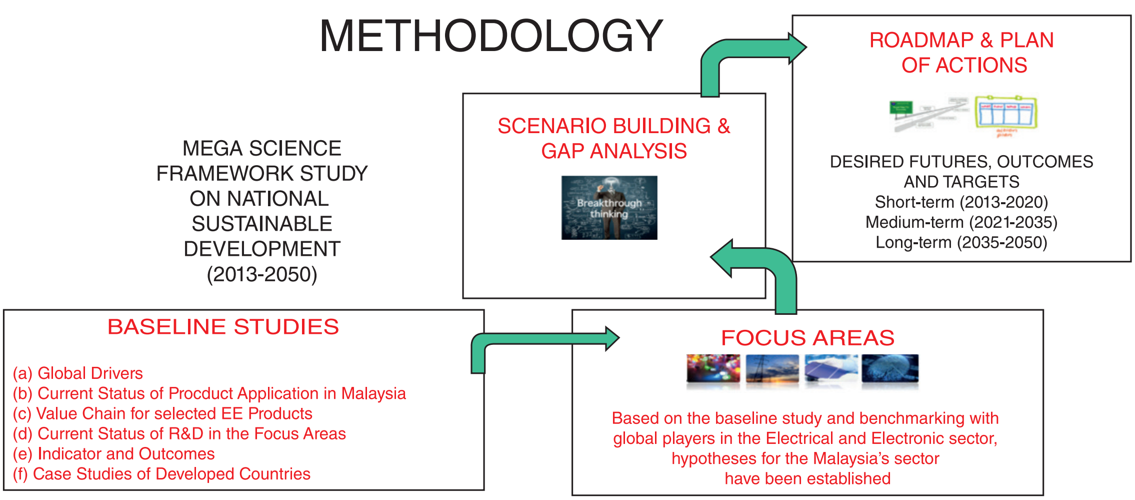

Figure 1.2 The Methodology of the Mega Science Study for E&E sector

baseline studies, obtaining stakeholder feedback, and discussing common concerns. At the end of the exercise, a set of action plans were drafted and strategised into short-term (2015-2020), medium-term (2021-2035) and long-term (2036-2050) roadmaps.

The backcasting approach (**Figure 1.3**) was employed for determining the desired future outcomes and associated action plans for Malaysia's E&E sector. The fundamental concept of the backcasting approach is to begin with the envisioned future, and then work backwards to the present while identifying the required steps to connect the desired future with the present conditions.

Backcasting is an increasingly employed strategic approach to urban planning, resource management, and research development. In contrast to the conventional method of *fore*-casting (predicting the future based on what is known today), backcasting has the potential of producing more options and creative solutions because it is unrestricted by the present known limitations. In essence, backcasting is an approach to *invent the future*, whereas forecasting is an *expectation of the future*, arrived at by extrapolating present conditions.

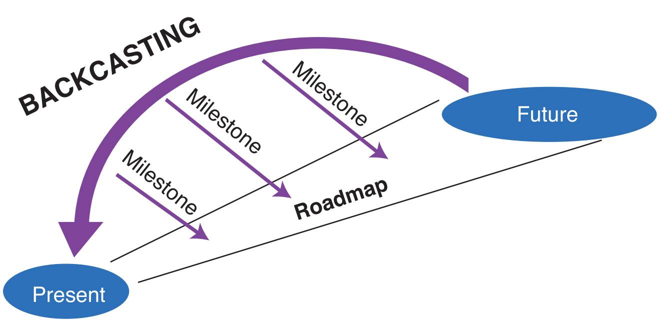

Figure 1.3 The backcasting approach of roadmap development begins by defining the desired future outcomes and then gradually working backwards to the present conditions while creating the development paths

1.6 KEY RECOMMENDATIONS

1.6.1 COMPOUND SEMICONDUCTOR

This section presents and analyses the impact of participating seriously in compound semiconductor industry in transforming and preparing the country to be one of the major player in the industry. The recommendations are designed not only to establish Malaysia foothold in compound semiconductor but to also expand and generate new technologies that will further strengthen Malaysia's role in the global market. They are designed to cover the whole timeframe starting from short-term up until long-term activities. The recommendations set out key principles for compound semiconductor subsector and detail explanations on the action plans can be explored in the main text of this document.

Recommendation 1: Wafer/substrate production in Malaysia

Malaysia should take part in wafer or substrate production business as this is the key component in semiconductor industries in the higher value chain segment. Sapphire is one kind of materials commonly used for compound semiconductor's substrate and holding among the biggest market share for LED devices. In this regard, Malaysia can venture in substrate/wafer production based on sapphire which comes from bauxite minerals. Setting up local players in this business opens up opportunities for the country to strengthen its research and development in substrate manufacturing. This can lead the research into exploring new materials for the wafer or solving issues related to the silicon wafer for compound semiconductors. Establishing and commercialising silicon wafer for compound semiconductor will be the ultimate objective and serve as the game changer in compound semiconductor that able to significantly reduce the LED/MMIC price.

For this recommendation, there are two areas that need to be given a head start in order to establish the foundation. A wafer/substrate (silicon and other materials) growing and production company/facilities should be established and secondly, the research and development centre should be created to look into new materials, new technologies and possibilities to use and mass-produced with high yield silicon as the wafer for compound semiconductor. A research university such as Universiti Kebangsaan Malaysia (UKM) with its micro and nanoelectronics research unit can be part of this activity. A Government-linked Company (GLC) can be created to start the wafer growing and production business. These initial initiatives can lead to the establishment of government-university-industry linkage as outlined in the remainder of this report.

Recommendation 2: Front-end LED device fabrication

Since Malaysia has already established itself in the lower-added value of the value chain, it is the time for the country to move-up to the higher-value added sectors and the local companies should play major role in this activity. Climbing the higher-value-added value chain means Malaysia must venture into LED device fabrication. This involves epitaxial on-wafer processes and device fabrication. In other words, Malaysia requires a compound semiconductor fabrication facility or foundry. This foundry can serve the fabrication of Monolithic Microwave Integrated Circuit (MMIC) as well. In this regard, at least two companies can be created one for the epitaxial process and another one for the device fabrication.

Local companies that currently involve in lower-end value chain for LED industry can be promoted to participate in the front-end segments. The private investment is needed to be involve in the epitaxial process and device fabrication before continuing in the existing lower-value chain such as LED packaging and lighting manufacturing. Fabrication and Research and Development centre created in the 1st recommendation can be part of this activity to help in the research activity and fabrication processes. Again, the government-university-industry linkage can be strengthened through this recommendation.

Recommendation 3: MMIC design house and fabrication facilities

The output value of semiconductors in Malaysia is around RM39 billion (2009), a global share of 5%. However, the majority of the semiconductor market in Malaysia is predominantly focused on silicon-based products and the semiconductor firms operating in Malaysia concentrate primarily on assembly and testing. Nevertheless, there are few CMOS IC design houses in Malaysia and one locally owned CMOS IC foundry (Silterra). Therefore, Malaysia should take this opportunity to participate in MMIC value chain from front-end all the way to the back-end. Local IC design house can created and one local compound semiconductor foundry can be developed to create the complete ecosystem. Together with substrate manufacturing industry and compound semiconductor foundry, the whole value chain can be covered, not only for the MMIC industry but also the LED device industry.

Recommendation 4: R&D in Compound Semiconductor

One of the key activities in moving up the value chain is deep involvement in Research and Development (R&D). This is the fundamental in any electronic industries that will determine the sustainability and future prospect of the industry. R&D is the key to success and often involves huge capital investment. Even though R&D is a risky business due to the huge cost and uncertainty in the commercialisation potential but without R&D, the success of the industry globally will be near impossible in the competitive market. Therefore, it is widely known that most of the big electronic companies in the world spend huge amount of money in the R&D.

In compound semiconductors, R&D activities can be divided according to the subsectors. For wafer or substrate manufacturing, R&D involves in researching new materials or new process technology to fabricate the wafer. Currently, about 4 types of materials are used for the compound semiconductor either still in research environment or has been commercialised. The materials are Gallium Nitride (GaN), Silicon Carbide (SiC) and silicon. Silicon, as the substrate for compound semiconductor, is still in its research stage.

Several players in this industry are working hard to materialise the possibility to use silicon as the substrate even though it seems impossible due to the crystal mismatch. Nevertheless, through R&D activities, at least in the research environment, silicon can be used as the substrate for compound semiconductor. Besides that, some other materials such as carbon nanotubes and graphene can be explored on their capabilities to merge with compound semiconductor in hybrid fashion to produce better devices. For instance, currently CNT capabilities have been explored together with Indium Gallium Zinc Oxide (IGZO) to produce complementary MOSFET. If this type of research reaches the mass production scale, the impact to the electronic industry as a whole will be huge. Malaysia should not be left behind in this race because we have the capability to take up the challenge to find new materials, devices and processes that can overcome current device limitations and offer a better alternative for future technologies.

Malaysia should also be heavily involved in the R&D activities of the compound semiconductor industry.As mentioned briefly in the first recommendation, there is a need to establish a government-university-industry university, especially a research university that has a role in R&D. A specialised unit or research centre or Centre of Excellence can be set up at the university to conduct all R&D activities related to compound semiconductors. This includes R&D on materials for substrate, silicon materials, new nanoscale materials such as CNTs, hybrid structure, flexible and transparent materials possibilities,improvement on epitaxial process. Apart from that, there is also R&D on new devices or designs for future electronic appliances. Facilities such as a clean room, molecular beam epitaxy and others that are available at UKM, for example, can be utilised to be the anchor in the R&D for compound semiconductor. However, the facilities have to be expanded to cater additional R&D activities for compound semiconductor.

Recommendation 5: Strategies for Roadmap

Several strategies or action plans have been prepared that covers the whole mega science framework for science, technology and innovation. The framework is divided into three stages of roadmaps. In this chapter, some of these strategies will be briefly discussed. The detail information about the activities/strategies for each term can be read in the main text.

The **short-term strategies** for the roadmap are purposely planned for the establishment of the compound semiconductor industry in Malaysia. Even though historically, Malaysia has participated in the compound semiconductor industry but the involvement is small and focusing only at the lower end of the value chain. In order to be a global player in this industry, it is highly recommended for Malaysia to play role in the higher value chain and this involves active participation by various sectors in the business. Thus, establishing the industry as a whole is vital to achieve the target as global player.

Among the high value activities/strategies planned for the short term are development of wafer/substrate manufacturing business, epitaxial wafer processing and LED and MMIC device fabrication. To illustrate, the availability of bauxite and sand minerals will be suitable to setup a sapphire and silicon wafer production. This is a huge capital investment activity but the return on investment is promising due to the highly reliant of electronic industries to the wafer/substrate. LED device manufacturing will involve existing LED industry in Malaysia that currently focusing on the lower value chain. These companies can be upgraded to move up the value chain into fabrication process.

Another crucial plan for the short term is to establish Malaysia owns consumer electronic company. This is similar the idea to establish Malaysia’s Samsung or Sony. This action plan is very important and vital to the successfulness and sustainability of the compound semiconductor and electronics industries in Malaysia. This company will produce consumer products that are priced competitively and will attract local market and eventually will gain significant market share. The products will serve as the market for underlying business including the wafer production, epitaxial processing business and LED/device fabrication.

At the end of the day, the consumer products will complete the ecosystem of the electronic industries in Malaysia and prepare them to participate in the global market. To initiate or encourage local consumer product companies, one grand challenge initiative can be opened nationwide to solve a local issue which will lead to one consumer product. For instance, Malaysia is going toward digital broadcasting in the near future and to ensure all people can receive the digital signal, every household need digital television or at least digital set top box. For this local issue, a grand challenge can be opened to any individual or organisations or companies to take the challenge to produce the digital set top box locally. This will encourage participants from various sectors and eventually, a digital set top box that is 100% made in Malaysia can be produced and will be used by most of the people in the country.

Hence, this digital set, from this product, the expertise, manpower, resources, suppliers, facilities and the complete value chain in the development can be established. This establishment will then continue their product development for other local consumption and might venture into products that can compete with other global brand. Apart from that, the smartphone is another product that can be developed locally; provided all the individual players in the complete value chain are ready to take the challenge to produce Malaysia's brand smartphone made 100% or close to 100% locally. Establishing a consumer product company in electronic industry is the catalyst that can drive Malaysia towards developed nation in the future.

The **midterm activities** expand the technology established in the short term plan. Basically, it involves activity that further enhances all the foundation that has been developed from the short-term initiatives across the whole sectors and subsectors. For instance, in substrate/wafer manufacturing established previously, the next stage will be exploration on new materials that can save the cost and increase the performance, efficiency and improve the production yield. This stage will heavily dependent on the R&D activities on the exploration, researching and development on the technology. This is important in order to sustain the presence of Malaysia compound semiconductor industry locally and globally. Without expansion and improvement on the current technology, the industry will face the risk of fierce competition from global players and might lose the cost competitiveness of locally produced products.

On top of that, Government support is needed to enhance the local market share through policy enforcement. Hence, the policy for LED adoption among the government agencies and public infrastructures should be set at 70% utilisation which means 70% of the lighting used in the country by the government office and street light should be LED. This will help to expand the local market share for LED industry and support the whole value chain in the LED production.

In the final stages, the **long-term plan** that spans between 2030 until 2050 emphasises heavily on the next generation technology. This will be the period where this will be the period where the Malaysia can be the global market leader. For this purpose, the focus for R&D team will be to identify and explore totally new technology that will contribute significantly to the compound industry and differentiate ourselves from the conventional approach.

This is the term where new novelty ideas can be proposed, developed and mass-produced that will extend Malaysia foothold in the global map. Among the new technology that can be explored and commercialised is flexible and transparent substrate that will have endless possibilities and attractive applications and will change the way electronic devices being use. Thus, further exploration in compound semiconductor and CMOS based semiconductor might benefit the medical, health institution and communication sectors.

Furthermore, a total integration between compound semiconductor and silicon based semiconductor at a high yield rate will lead to significant changes to the electronic industry which will definitely bring the cost down due to the low cost of silicon and improve the performance due to the advance capability of the compound semiconductor. In general, as long as Malaysia is working towards the expansion and introduction of new technology to support the industry, the dream of maintaining its sustainability which then can lead the global market will be achievable.

1.6.2 ENERGY GENERATION, TRANSMISSION AND DISTRIBUTION

Significant change is underway in the world of energy and many factors are influencing this change – events, economic factors, energy security concerns, government policies, environmental goals and innovation are the dominant factors driving this change. Recent events include:

- The future of the nuclear sector has become uncertain after the accident at Fukushima;
- The Arab Spring that has led to significant political change in the Middle East and created uncertainty about future supplies from the region; and
- The revolution of shale gas that has started to spread from North America to other parts of the world and of which the technology is now being applied to tight oil.

Recommendation 1: Stability of the energy sources

Oil prices have reached their highest annual average since records have been kept Energy Policies Government policies in every country in the world influence both national and international energy architecture. Given the strategic significance of the industry, this has been expected. It is also expected that national interests will continue to dominate energy policies. However, at present, there is a patchwork of policies within most nations and internationally.

Energy Efficiency

According to the International Energy Agency's 2011 World Energy Outlook, global energy demand is expected to increase by one-third from 2011 to 2034. Demand-side management is needed to curb the increase as much as possible, with energy efficiency holding the key. Significant improvements in energy efficiency are possible with known technologies. Both transportation and power generation make use of less than one-third of their primary energy input. It is well known that deployment of energy efficiency technologies requires up front capital investment that is paid back over a period of time. There are many other market challenges, such as asymmetric information flow and the 'principal-agent' problem.

Climate Change

According to the IEA, the global energy-related emissions of CO_2 had increased by 4.3% to a record of 30.4 gigatonnes in 2010. Nevertheless, if this trend persists, it is very likely that the global average greenhouse gas concentrations will exceed 450 ppm. Since the start of the Great Recession, tackling climate change has become increasingly difficult due to fiscal challenges faced by many governments around the world. There is a growing recognition of the need for 'adaptation' as well as 'mitigation' as witnessed during COP-17 in Durban.

Meanwhile, there is a spurt in innovation in low-carbon energy technologies. The biggest challenge these start-ups face is a lack of capital investment for scaling up their technologies and a lack of understanding of the energy industry structure. A rapid deployment and scale up of new innovations require closer partnerships between the incumbents and new entrants. The incumbents should increase their investments in new high-risk, low-probability technologies and new entrants should leverage the experience and expertise of the incumbents. In the current economic climate, lack of financing has become a major impediment for the scale up and rapid deployment of new technologies. As such, Energy industry leaders should become the catalysts for these partnerships.

Innovation

This decade is crucial for evaluating the multiple pathways to a different and more sustainable energy future. The world is relying on major technological innovations in the energy sector to create this future. The large capital stock on both the demand and supply side of the energy equation makes revolutionary change nearly impossible. Nevertheless, the energy sector should strive for a fast evolution and rapid scale up of new technologies, from laboratory to large-scale applications. This will require significant new investments in technology development, a new generation of skilled workforces, and new plants and equipment.

Recommendation 2: Nuclear power development

Nuclear energy has a low life cycle carbon burden and is more competitive if a carbon penalty is imposed than alternative commercial energy sources. The Greenhouse Gas (GHG) emission level from power generation sources to nuclear energy is well-justified in terms of supply security, environment and economics for base load. However, the main issues to be addressed are policy considerations, infrastructures such as human resource development, technology, act and regulations, and public acceptance.

On 26th June 2009, the Prime Minister's cabinet has agreed to consider nuclear energy as one of the options for electricity generation post 2020 particularly in Peninsular Malaysia. Government also will set up Nuclear Power Development Steering Committee (JPPKN) and three (3) Working Committees and allocate RM25 million for a period of 3 years to implement activities under JPPKN.

Then, in 16 July 2010, the Cabinet agreed to adopt National Nuclear Policy as a guideline for the development of nuclear sector for electricity generation and non-electricity generation. The main players for this policy are the Ministry of Science, Technology and Innovation (MOSTI) and Ministry of Energy, Green Technology and Water (KeTTHA). From these two decisions, a new energy policy was formulated to include nuclear as one of the option to electricity generation sources (Daud 2010).

Recommendation 3: Electrical and Electronics Industry

The Electrical & Electronics (E&E) industry is the leading sector in Malaysia's manufacturing sector, contributing significantly to the country's manufacturing output (26.94%), exports (48.7%) and employment (32.5%). In 2010, the gross output of the industry totalled RM158.7 billion (USD50.94 billion), exports amounted to RM234.5 billion (USD74.7 billion) and created employment opportunities for 325,696 people. The major export destinations are USA, China and Singapore while the major import destinations are Taiwan, USA and South Korea.

Over the years, Malaysia's E&E industry has developed significant capabilities and skills for the manufacture of a wide range of semiconductor devices, including photovoltaic cells and modules, high-end consumer electronics, as well as Information and Communication Technology (ICT) products. The E&E manufacturers in the country have continued to move-up the value chain to produce higher value-added products. This includes intensification of R&D efforts and outsources non-core activities domestically (KeTTHA 2013). The E&E industry in Malaysia can be categorised into the following four subsectors:

Consumer Electronics

This subsector includes the manufacture of LED television receivers, audiovisual products such as Blu-ray disc players/recorders, digital home theatre systems, mini disc, electronics games consoles, and digital cameras. The sector is represented by many renowned Japanese and Korean companies which have contributed significantly towards the rapid growth of the sector. Moreover, leading companies are now undertaking R&D activities in the country to support their global and Asian markets. Exports of consumer electronic products in 2011 amounted to RM22.36 billion (USD8.7 billion).

Electronic Components

Products or activities, which fall under this subsector, include semiconductor devices, passive components, printed circuits and other components such as media, substrates and connectors. The electronic component sectors are the most important subsectors, accounting for 36% of the total investments approved in the electronics sector in 2011.

The subsector is mainly dominated by the semiconductor players especially MNCs, mainly undertaking the assembly and test activities. However, the development of the semiconductor cluster has shown a gradual increase over the years. More companies are expanding research, design and development activities in their operations with less emphasis in the manufacturing of low end products. The increase in demand for the miniaturisation and high performance devices for mobile, automotive, and green applications has further stimulated the growth of outsourcing activity in the semiconductor industry. Semiconductor products constituted of export value RM107 billion (USD34.4 billion). It contributed 93.4% of the total export of electronic components or 50.8% of the total electronics exports for 2011.

Industrial Electronics

This subsector consists of multimedia and information technology products such as computers, computer peripherals, telecommunication products and office equipment. The Industrial electronics subsector accounted for 6% of the total investment approved in the electronics sector in 2011. In 2011, the majority of the investments approved amounting to RM2.6 billion were from Electronic Manufacturing Services (EMS) companies producing low vol. high mix products for various applications such as medical, aerospace, oil and gas, and telecommunication.

Electrical

The major electrical products produced under this subsector are lightings, solar related products and household appliances such as air-conditioners, refrigerators, washing machines and vacuum cleaners. In 2011, investments in the subsector amounted to RM9.7 billion, of which 91.4% was dominated by foreign investments while domestic investments accounted for 8.6% of the total approved investments in 2011. With exception to the solar industry, most of the investments in the electrical subsector were from the domestic sources, especially in the production of household appliances and electrical components. Malaysia is home to many of the largest and renowned solar players such as First Solar and AUO-Sunpower. The presence of these MNCs has contributed to the development of various products under the solar cluster.

Recommendation 4: R&D in Energy Generation, Transmission and Distribution

There are several R&D institutions in Malaysia that are involved in both scientific and economic research, such as follows:

GreenTech Malaysia (formerly known as Pusat Tenaga Malaysia)

PTM is an independent and non-profit organisation established in May 1998 to fulfil the need for a national energy research centre in Malaysia. Its core activities are energy planning and research, energy efficiency and technological research, development and demonstration. Their responsibilities also include data gathering. PTM also functions as a one-stop energy agency for linkages with the universities, research institutions, and industries other national and international energy organisations. The following are its main functions:

1. Agent for public and private sectors;
2. Guardian/repository of a national database;
3. ‘think-tank’ on energy via consultancy services;
4. Promoter of national energy efficiency programme; and
5. Coordinator and lead manager in energy research, development and demonstration projects.

TNB Research Sdn Bhd

TNB Research Sdn Bhd, a wholly owned subsidiary of TNB, was formed in March 1993 to undertake R&D activities for TNB. It provides quality assurance, laboratory testing and consultancy services in energy and environment preservation for TNB and other energy suppliers in Malaysia.

PETRONAS Research Scientific Services Sdn Bhd (PRSS)

PRSS is a subsidiary fully owned by PETRONAS which carries out R&D's activities for the petroleum industry.

SIRIM Bhd (SIRIM)

SIRIM is involved in R&D activities for the industrial sector. In the field of energy, its activities are focused on renewable energy and energy efficiency.

Recommendation 5: Transition towards the Hydrogen Economy

The transition towards the hydrogen economy, to substitute the current hydrocarbon economy, will begin at the end of the long term (2036-2050). Namely, hydrogen acts as an energy carrier and is environmentally cleaner source of energy to end-users, particularly in transportation, residential and commercial sectors applications, without release of pollutants (such as particulate matter) or carbon dioxide at the point of enduse. In the short term (2015 - 2020) and medium term (2021 – 2035) demonstration projects on renewable hydrogen production and fuel cell should be funded. The concept of renewable hydrogen and regenerative fuel cells for rural electrification should be introduced and the competiveness of this concept compared to conventional the renewable energy hybrid battery system.

Recommendation 6: Distributed Grid for Sabah and Sarawak

The Distributed Grid (DG) consists of a range of smaller-scale and modular devices designed to provide electricity, and sometimes also thermal energy, in locations close to consumers. They include fossil and renewable energy technologies (e.g. photovoltaic arrays, wind turbines, microturbines, reciprocating engines, fuel cells, combustion turbines, and steam turbines); energy storage devices (e.g. batteries and flywheels); and combined heat and power systems. Furthermore, the distributed grid offers solutions to many of the nation's most pressing energy and electric power problems, including blackouts and brownouts, energy security concerns, power quality issues, tighter emissions standards, transmission bottlenecks, and the desire for greater control over energy costs.

To illustrate, it is proposed for a Borneo-wide distributed grid be created, that incorporates solar and wind power plants in Sabah and Sarawak. The existing fossil and hydro power plants are considered. Models for different power plants are first reviewed for this proposal. As the distributed grid gets more complex and integrated, better data acquisition and control systems are needed to control load flow and minimise power outages. Power outages usually initiate from a small area and propagate over larger areas causing cascaded power failure. Considering this as well as the distributed power generation from renewables, an Internet based distributed data acquisition and control network is needed.

Recommendation 7: Rural Transformation to Net Neutral Sustainable Energy Community

There are four main issues faced by rural villages in Malaysia, namely urban migration that stagnates the rural economy abandoned villages no rural income generation and lack of education. These issues can solved by introducing innovative renewable energy technology affordable to economically-depressed grid-less remote areas of the country and generates rural economic activities. An eco-framework solution to achieve net neutral renewable energy community or zero-energy community must be developed during the short-term (2015-2020), and medium-term (2021-2035) in remote areas off grids of orang *Asli* communities in Semenanjung Malaysia and rural communities of Sabah and Sarawak. The net neutral renewable energy concept emphasises using all possible cost-effective renewable energy technology and demand-avoidance strategies Malaysia is located in the tropical region where the sky conditions are diffused in nature and low wind speed. Thus, there are challenges in technological and fundamental aspects of renewable energy systems that must be address which can be taken by universities and related research institutions.

Apart from that, education packages must be developed within the community to achieve desired awareness in net neutral concept renewable energy which provides hands-on training on applications of renewable energy with basic education and societal awareness. The net neutral Sustainable Energy Community concept will then create communal social activities and development of location-specific cottage industries.

Recommendation 8: Strategies for Roadmap

Short-term Action Plan (2015-2020)

The short-term plan is predominantly industry-driven, as many developed countries around the world are expected to achieve the following action plans on energy efficiency and green energy such as:

a. Smart grid implementation;

b. Net neutral renewable energy sustainable system;

c. Effective and efficient solar energy;

d. Alternative energy source of fuel; and

e. Efficient energy distribution.

Medium-term Action Plan (2021-2035)

The medium term action plan is to further develop and expand the energy industry in the country to embrace new technology for renewable and green energy. Application of new innovative technology is important, especially in producing renewable and green energy. Hence, several of the action plans targeted for the medium term are as follows:

a. Effective smart grid implementation;

b. Effective and efficient nuclear energy generation;

c. Improvement of solar energy;

d. Alternative energy source of fuel; and

e. Efficient and effective energy distribution and transmission.

Long-term Action Plan (2036-2050)

The final term action plan is themed as the next generation technology which suggests futuristic product development for energy supply stability. This action plans are crucial to achieve the final scenario. The only way to be the market leader is by leading technological advancement faster than the competitor. The long term action plans are as follows:

a. Advanced smart grid implementation

b. Carbon neutral sustainable community

c. Effective and efficient solar energy

d. Build advanced designs of nuclear plant

e. Transition to the Hydrogen economy

1.6.3 SOLAR AS AN EFFICIENT RENEWABLE ENERGY

Solar energy is an environment-friendly renewable energy resource with widelyidentified potentials to address worldwide concerns of energy security and environmental protection. Driven by constant technological improvements and ever-decreasing deployment costs, the global solar energy industry is expected to expand to a USD155 billion industry by 2018. Malaysia can potentially reap substantial socio-economic benefits from solar energy industry because much of the necessary groundwork are already in place, including specific policies on renewable energies, partnershipswith advancedsolar PV multinational corporations, deployment of small-scale solar PV and thermal applications, and establishment of solar energy R&D centres.

However, Malaysia's current operations on the solar energy value chain are fragmented, mainly serving as a low-cost PV manufacturing hub for foreign PV firms. It is of particular concern whether Malaysia can sustainably remain as a cost-competitive investment destination option with the emergence of China, India, Vietnam and Indonesia with similar low-cost models in direct competition for FDIs.

In contrast, Malaysia's under-developed domestic market for solar energy, as indicated by its low installed capacity compared to regional countries — is a substantial hurdle in development of the local solar energy industry. Policy refinements and suitable market-intervention measures must be implemented to enlarge the local market size. Therefore, we propose the following strategy to further develop Malaysia's solar energy sector:

Recommendation 1: Establish a silicon ingotproduction industry in Malaysia

Over 90% of solar cells produced worldwide are currently based on crystalline silicon wafers which are expected to dominate the market over the next 10 years. This growing demand presents an immediate opportunity for the Government to establish asilicon ingot production industry in Malaysia, which can be targeted to be operational by as early as next year (2015) due to the low technical barriers for entry asthe standard production equipment for industrial-scale ingot-growing can be bought off the shelf. Potential collaborators for this venture include the Solar Energy Research Institute of UKM, a local R&D institute with well-established solar energy research programmes, and PV Crystalox Solar, one of the world's largest independent producers of silicon ingot.

Recommendation 2: Production of silicon feedstock in Malaysia

Silicon and glass form the largest cost component in the manufacturing of silicon and thin-film PV cells, but most PV firms operating in Malaysia currently imports these feedstock components from abroad. For that reason, Malaysia has the potential to become a global producer of silicon, given the abundance of high-grade silica sand in Malaysia, and globally rising demands. Hence, the Government, via partnerships with Malaysian firms and investors should capture these high value-added operations by setting up silicon production plants, which can be operational as early as 2018. Locally-sourced silicon feedstock would present a significant costadvantage for the proposed ingot-growing industry in ***Recommendation 1***, and for the local PV manufacturing operations along the entire value-chain.

Recommendation 3: Solar water heating for public hospitals

One of the most economically attractive and immediate applications of solar heating is in the public healthcare system. In a case study at the Hospital Universiti Kebangsaan Malaysia (HUKM) where solar water heating is employed to replace the conventional LPG boilers results in a massive 50% LPG savings of 29,000 kg/year with approximately CO_2 reduction of 64,000 kg/year. An estimated market potential worth over RM200 million exists for the system to be deployed nationwide to a prospect of 135 Government hospitals.

Recommendation 4: Poverty eradication using targeted FiT scheme and corporate sponsorships of solar panels

About 5% of Malaysian households earn less than RM1, 000 per month, an income bracket which lies very near to the national poverty line.Under a special quota allocation of the FiT schemetargetedfor the poor, these low-income households will stand to earn additional income of RM300 to RM500 per month when corporate-sponsored solar panels are installed at their houses. The corporate sponsorships of the solar panels can be wooed with tax breaks and other reasonable incentives. The installations and post-sales services of the solar panels can also create jobs and next-door business opportunities which can be filled by the targeted communities themselves, thus, further alleviating their socio-economic standing.

Recommendation 5: Net zero-energy government office buildings for reduced energy expenditures

A "net zero-energy building" is a building with zero or very-low net consumption of energy. In other words, the total amount of energy needed by the building is met by the renewable energies self-generated on the site of the building itself. This is achieved via incorporation of a range of energy efficiency measures and features into the holistic design of the building, which includes building-integrated photovoltaics, natural lighting and ventilation, high-efficiency electrical equipment, high-performance thermal insulation, and proper building orientation relative to the sun's position.

In addition, net zero-energy buildings have higher resale values, and thus are also insulated against the effects of energy price fluctuations. These advantages can be significantly scaled up with the implementation of net zero-energy buildings for future developments of government offices. A landmark example of a net zero–energy building in Malaysia is the Pusat Tenaga Malaysia (PTM) located in Bandar Baru Bangi.

Recommendation 6: Industry-wide application of solar process heat for Malaysia's agricultural and marine products

The agriculture industry contributes up to 12% of Malaysia's GDP, in which the post-harvest drying process is important to extend the commodity shelf life. Although solar-drying technology is technically simple, its take up rate is very low compared to diesel-powered dryers or traditional sun drying.

Solar-drying offers significant cost savings as compared to the diesel-powered dryers which are subjected to escalating fuel prices. In addition, typical solar-drying systems are also simple enough for rapid deployment with a typical payback period of two to three years years, while also offering higher efficiencies compared to the traditional sun drying. Examples of potential applications include solar-drying for oil palm fronds, cocoa, anchovies and seaweeds; including solar-assisted air conditioning for aquaphonic systems for the simultaneous production of foods and energy.

Recommendation 7: Commit GLC investments into rapid-prototyping and technology commercialisation of local R&D

Malaysia has a number of well-established research centres with solar energy research programmes (refer Chapter 8 Baseline Study). The government's various investment arms should commit investments into promising new technologies produced by the local R&D centres, and catalyse the creation and incubation of solar technology start-up companies. For the case of proven technologies, the partnerships should result technology commercialisation and industrial-scale production, which will then be able to seize the advantage of the cheap, locally-produced silicon feedstock resulting from Recommendation 1 and Recommendation 2. The end result is Malaysia would be able to own up the *entire* technology value chain, where layer upon layer of value-added components is generated by Malaysian firms starting from the upstream R&D and PV cell manufacturing and module assembly, to the downstream product installation and services.

Recommendation 8: Strategic coordination and intensification of R&D via the establishment of a national Centre of Excellence for Solar Energy

A national centre of excellence is needed to strategise and coordinate the solar energy research programmes currently carried out in more than 10 R&D centres across the country. This is to ensure non-overlapping research focus, as well as catalysing greater research collaborations. Among the specific research focus areas which are of strategic importance are process optimisations, cell efficiency improvement, safer and cheaper processes, high-performance graphene-based solar cells, advanced bio-inspired materials and next-generation nanostructured solar cells. The proposed centre of excellence can also provide related training and support, as well as act as a one-stop reference point for investors and interested public.

Recommendation 9: Stimulate the market demand for solar energy via Government mandates

Malaysia's under-developed domestic market for solar energy is a substantial hurdle in developing the local solar energy industry. The government, via suitable market-intervention measures, can help stimulate the domestic demands by instructing that all government facilitiesbeequipped with solar-energy harvesting systems which would then pay off in reduced energy expenditures over the long-term. Market demands from the private sector can be stimulated using similar means, such as offering financial incentives to property developers that incorporate Building-Integrated Photovoltaic (BIPV) materials or solar water heating systems in their developments.

Recommendation 10: Policy refinement, governance improvement and publicity drive to catalyse growth of consumer demand for solar energy.

The development of renewable energies in Malaysia is generally hampered by the following regulatory shortcomings:

- Limited public access to the national grid and the Feed-in-Tariff (FiT) scheme, creating a situation of monopsony;
- Massive subsidies of fossil fuels prolonging public reliance and consumption;
- The absence of carbon-tax (penalty for carbon dioxide emission) applied to power producers, industries and the general public makes fossil fuels a naturally preferred power source;
- Difficulty in obtaining planning permissions and environmental licensing from the authorities to set up RE installations;
- General lack of strategised publicity drives to increase awareness and encourage investments in renewable energies; and
- Long period of investment payback.

For that reason, we recommend that the FIT quota be suitably increased to accommodate market-demands, which will in turn provide additional momentum for Malaysia to attain grid-parity (a situation where the costs of renewable energies have decreased significantly to be comparable to those of grid-electricity). The implementation of carbon-tax and reduction of fuel subsidies will also potentially contribute to the demand for solar energy systems. Apart from that, the demands can also be stimulated via public awareness campaigns and advocacy programmes, and setting up of affordable credit facilities.

Recommendation 11: Implementation of roadmap and action plans over short, medium and long-term for comprehensive development of Malaysia's solar energy industry

The action plans and roadmap for the comprehensive development of Malaysia's solar energy industry are presented in Chapter 10, which cover 4 different change-dimensions, namely R&D Technology Goals; Institutional Framework; Infrastructure Development; Value Chain and Market Development.

The short-term action plan (2015–2020) is industry-driven because many countries around the world are expected to achieve grid-parity circa 2020. This will drive vol. demands for solar energy systems with improved efficiencies at constantly pushed-down costs. To capitalise on this market growth, the short-term plan is focused on transforming Malaysia's solar energy industry into a major national industry, which can be realistically accomplished within 5 years' time.

A critical step in this near-tem plan is for Malaysia to fully develop and take ownership of the entire supply chain of the silicon solar cell industry — beginning from the capabilities to purify silicon, grow ingots, wafer processing, solar cells manufacturing and panel assembly. This can be done in 2 phases, namely silicon wafer growth in the first phase of 2015; and silicon purification in the second phase of 2018. The committed investments will pay off in a short time considering the spillover applications of this technology into Malaysia's well-established Integrated Circuit (IC) fabrication industry.

The medium-term action plan (2021–2035) is designed to expand the Malaysian global market share of solar energy systems. It is envisioned that Malaysian solar energy conglomerates will be among the world's top-10 producers, backed by a mature domestic market that has achieved the point of grid-parity. The market is expected to continue to grow in many developing countries, which presents trade potential for Malaysia.

This technology-driven action plan also sets out to put Malaysia at the forefront in advanced-generation solar energy technologies via strategic research focus areas and technology commercialisation. These would include breakthrough cell efficiencies exceeding 25%, the use of concentrators, organics solar cells, silicon cell of less than 50 microns, and thin-films technologies.

The long-term (2036-2050) plan is research-driven, focusing on nanotechnology, organics and bio-inspired solar cells, quantum dots, and multi-multi junction cells. Thelong-term desired scenario is having Malaysia as a solar energy R&D powerhouse, producing world's top-10 R&D output and novel solar energy systems, such quantum solar cells and solar-energy harvesters in outer space. Fossil fuels are expected to be fully-phased out in the domestic energy-mix, replaced by solar energy sources.

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ACRONYMS

a-Si	—	Amorphous Silicon
AAIBE	—	Application under Electricity Industry Trust Account
AAIBE	—	Application under Electricity Industry Trust Account
AC	—	Alternating Current
Al203	—	Aluminium Oxide
Al2O3	—	Aluminium Oxide
ASM	—	Academy of Sciences Malaysia
BIPV	—	Building Integrated PV
BIPV	—	Building Integrated PV
CCGT	—	Combined Cycle Gas Turbine
CdTE	—	Cadmium Telluride
CdTe	—	Cadmium telluride
CEB	—	Central Electricity Board
CETREE	—	Centre for Education, Training, and Research in Renewable Energy and Energy Efficiency
CIS/CIGS	—	Copper Indium Gallium Selenide
CO2	—	Carbon Dioxide
COE	—	Centre of Excellence
CoERE	—	Centre of Excellence for Renewable Energy
CPV	—	Concentrating PV
CPV	—	Concentrating PV
CSP	—	Concentrated Solar Power
CSP	—	Concentrated Solar Power
CuInSe2	—	Copper Indium Gallium Diselenide
DANCED	—	Danish Cooperation for Environment and Development
DDI	—	Domestic Direct Investment
DG	—	Distributed Grid ()
DG	—	Distributed Grid (DG)
DSSC	—	Dye-Sensitised Solar Cell
E&E	—	Electrical and Electronics
EC	—	Energy Comission
EGAT	—	Electricity Generating Authority of Thailand
EIA	—	Energy Information Administration
EMS	—	Electronic Manufacturing Services
EMS	—	Electronic Manufacturing Services
EGAT	—	Electricity Generating Authority of Thailand
EPCC	—	Engineering, Procurement, Construction, and Commissioning
EPPs	—	Entry Point Projects
EPU	—	Economic Planning Unit
ETP	—	Economic Transformation Programme
FDI	—	Foreign Direct Investment
FET	—	Field Effect Transistors
FiT	—	Feed-in-Tariff
FRIM	—	Forest Research Institute of Malaysia
GaAs	—	Gallium Arsenide
GaAsP	—	Gallium Arsenide Phosphide
GaN	—	Gallium Nitride
GaP	—	Gallium Phosphide
GDP	—	Gross Domestic Product
GEF	—	Global Environmental Facility
GHG	—	Greenhouse Gas
GLC	—	Government Linked-Company
GLE	—	Government Linked Government
GNI	—	Gross National Income
GTFS	—	Green Technology Financing Scheme
GHG	—	Greenhouse Gas
GW	—	Gigawatts
HBT	—	Heterojunction Bipolar Transistor
HUKM	—	Hospital Universiti Kebangsaan Malaysia
HVPE	—	Hydride Vapour Phase Epitaxy
IC	—	Integrated-Circuit
ICT	—	Information, Communication and Technology
IEA	—	International Energy Agency
IPCC	—	International Panel on Climate Change
IPP	—	Independent Power Producer
IPP	—	Independent Power Producers
JDA	—	Joint Development Area
JOA	—	Joint Development Area
JPPKN	—	Nuclear Power Development Steering Committee
JPPPET	—	Planning and Implementation Committee Meeting Electric and Tariff Supply
KED	—	Kinta Electrical Distribution Co. Ltd.
KeTTHA	—	Ministry of Energy, Green Technology and Water
kV	—	Kilovolts
LADA	—	Langkawi Development Authority
LED	—	Light Emitting Diode
MARDI	—	Malaysian Agricultural Research and Development Institute
MESFET	—	Metal-Semiconductor Field Effect Transistor

MESITA — Malaysia Electricity Industry Trust Account
MEWC — Ministry of Energy, Water and Communications
MEWC — Ministry of Energy, Water and Communications
MIEEIP — Malaysia Industrial Energy Effeciency Improvement Project
MIEEIP — Malaysian Industrial Energy Efficiency Improvement Project
MMIC — Monolithic Microwave Integrated Circuit
MMW — Millimetre Wave
MNPC — Malaysia Nuclear Power Corporation
MNS — Malaysian Nature Society
MOSTI — Ministry of Sciece, Technology & Innovation
MW — Megawatts
NEB — National Electricity Board
NEDO — New Energy Development Organisation
NERC — Nature Education and Research Centre
NUR — Northern Utility Resources
PETRONAS — Petroleum Nasional Berhad
PHEMTP — Pseudomorphic High-Electron Mobility Transistor
PhoLED — Phosphorescent Organic LED
PRHEP — Perak River Hydro Electric Power
PTM — Pusat Tenaga Malaysia
PTNJ — Perbadanan Taman Negara Johor
PV — Photovoltaic
PVMC — PV Monitoring Centre
PVT — Photovoltaic thermal collectors
QCC — Quality Control Centre
R&D — Research and Development
RE — Renewable Energy
REPPA — Renewable Energy Power Purchase Agreement
RF — Radio Frequency
RFIC — Radio Frequency Integrated Circuits RE
ROI — Research, Development and Innovation
SC — Silicon Carbide
SECB — Sarawak Enterprise Corporation Berhad
SEDA — Sustainable Energy Development Authority Malaysia
SERI — Solar Energy Research Institute
SERI — Solar Energy Research Centre
SESCO — Sarawak Electricity Supply Corporation
SESIB — Sabah Electricity Sendirian Berhad
SET — Science, Engineering and Technology
SEB — Sarawak Energy Berhad
SiC — Silicon Carbide
SIRIM — Standards and Industrial Research Institute of Malaysia
SMART — Specific, Measureable, Attainable, Relevant, Time-bound
SP — Singapore Power Limited
SREP — Small Renewable Energy Programme
STI — Science, Innovation & Technology
TF-Si — Thin-Film Silicon
TFPV — Thin-Film PV cell
TFSC — Thin-Film Solar Cell
TNB — Tenaga Nasional Berhad
TVWS — TV White Spaces
UHB — Ultra-High Brightness
UiTM — Universiti Teknologi Mara Malaysia
UKM — Universiti Kebangsaan Malaysia
UMS — Universiti Malaysia Sabah
UNDP — United Nations Development Programme
UNFCCC — United Nations Framework Convention for Climate Change
UNIMAS — Universiti Malaysia Sarawak
UNITEN — Universiti Tenaga Nasional
USM — Universiti Sains Malaysia
UTAR — Universiti Tunku Abdul Rahman
UTM — Universiti Teknologi Malaysia

CHAPTER 1
COMPOUND SEMICONDUTOR: BASELINE STUDY

A compound semiconductor is composed of elements from two or more groups of the periodic table. For example, a III-V compound semiconductor is composed of group III material (boron, aluminium, gallium, indium) and group V material (nitrogen, phosphorus, arsenic, antimony, bismuth). The range of combination possibilities is quite broad, as these elements are able to form binary (combination of two elements such as gallium arsenide, GaAs), ternary (three elements such as Indium Gallium Arsenide, InGaAs) and quaternary combinations (four elements such as aluminium gallium indium phosphide, AlInGaP).

Several interesting properties are associated with compound semiconductors, including wide bandgap and high electron mobility. The potential of these properties is vast, as they enjoy substantial performance improvements over their silicon-based counterparts. These advantages include the ability to operate at higher temperatures, a higher power density, higher frequencies, and higher voltages. Such properties are suitable for inclusion in the future's demanding electronic systems, particularly in Radio Frequency (RF) or Millimetre Wave (MMW) applications.

In addition, due to their direct bandgap properties, as opposed to the indirect bandgap of silicon material, they are capable of generating light from electricity and converting light back into electricity. This has made compound semiconductors the chosen material for LED and solar technology applications.

The increasing demand of future advance wireless communications, photonic devices, power semiconductors, solar, and LED applications, is the driver for the compound semiconductor industry. Hence, compound semiconductor technology provides the key enabling materials that will drive a wide range of next generation technologies.

This chapter will explore the technology, trends, demands, and future prospects of compound semiconductors in the electrical and electronic sectors. Emphasis will be placed on three different industries closely related to compound semiconductor, namely substrate manufacturing, light emitting diodes (LEDs), and monolithic microwave integrated circuit (MMIC). Using this baseline study, the direction of compound semiconductor technology can be predicted and suitable recommendations will be tabled-out to be one of the players in this industry.

1.1 TECHNOLOGY REVIEW OF COMPOUND SEMICONDUCTORS

A compound semiconductor is a semiconductor made from a combination of several elements, such as element III and element V; to form a III-V semiconductor. Historically, semiconductors have played a major role in electronic industries. Since several decades ago, active devices built from a semiconductor material had shaped and transform the electronic industries towards achieving technology greatness.

Figure 1.1 depicts the timeframe of development for active devices. Vacuum tubes have been used for more than 50 years and are still being used today in several niche areas, such as high power-bandwidth RF

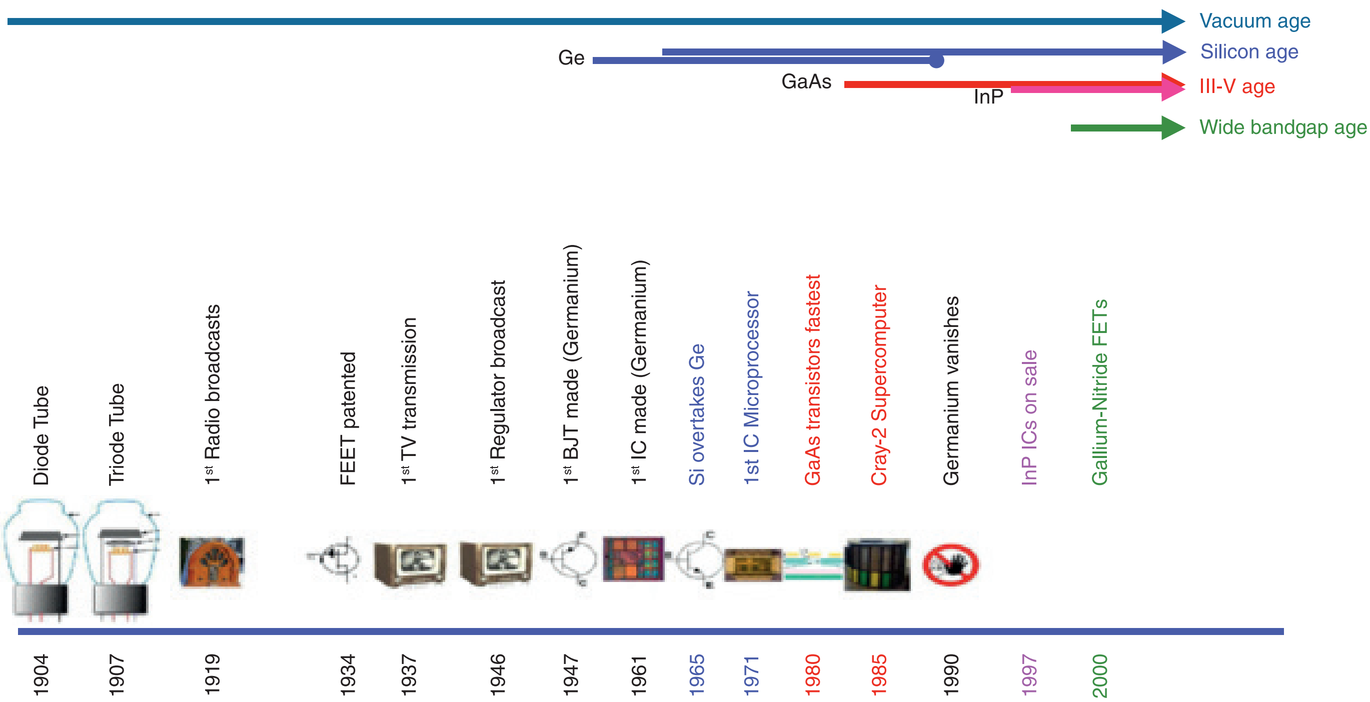


Figure 1.1 The History of Active Devices

Source: Scott & Parker

amplifiers. The vacuum tubes enabled the electronics revolution and allowed several important technologies including radio communication, sensitive measurement, and broadcast entertainment.

The silicon era started during the 1960s, about a decade after germanium devices were developed and had formed a better material system. The silicon family gained popularity and wide acceptance in far less time than tubes. This rise was driven simply by the robustness of the material, lower power consumption, and reduced size, together with the appearance of numerous applications from the ability to form an integrated circuit through a better manufacturing process. This was a rapid development.

Meanwhile, physicists and material experts had been experimenting with better solid-State material systems. One that caught the attention of researchers was the III-V systems. One of the earlier III-V systems used was Gallium-Arsenide (GaAs). GaAs compound semiconductors formed from crystals of Gallium and Arsenic offered several advantages; the charge carrier's mobility was eight times that than silicon, increasing device speed and making the bandgap wider, allowing it to emit light. Circa 1980, GaAs-based devices took the production electronics speed record offering interesting characteristics. This was the era of satellite TV, supercomputers, and LED.

The III-V compound semiconductor took less time to reach commercial viability than silicon. Within a short duration, several mainstream devices were developed such as MESFETs, HBTs/ and HEMTs. **Table 1.1** illustrates certain semiconductor devices and their performance characteristics. The first three materials

Table 1.1 Semiconductor devices comparison

Material	Electron Mobility (cm^2/Vs)	Peak Velocity (10^7 cm cm/s)	Frequency Range (GHz)	Noise Figure	Gain	Maturity
Si	900-1,100	0.3-0.7	<20	Moderate	Moderate	Mature 12-in Wafer
SiGe	2,000-300,000	0.1-1.0	10-40	Lower	Better	Mature 6-in Wafer
SiC	500-1,000	0.15-0.2	15-20	Poor	Lower	4-in Wafer
GaAs	5,500-7,000	1.6-2.3	>75	Lower (F_{min}-1.1)	Higer (G_{ass}=9)	3,4,6-in Wafer
GaN	400-1,600	1.2-2.0	20-30	Poor	Lower	2-in Wafer
InP	10,000-12,000	2.5-3.5	>115	Lower (F_{min}=0.9)	Higer (G_{ass}=11)	2-in Wafer

in the Table are from group IV, while the last three are compound semiconductors from group III-V. It can be seen from the table that compound semiconductors have better overall performance than single elements, especially silicon. Thus, due to these superior characteristics, compound semiconductors have seen tremendous development and popularity in producing high performance, high voltage, power and frequency applications.

1.1.1 WAFER/SUBSTRATE

In electronics, a wafer or substrate is a thin slice of semiconductor material, used in the fabrication of integrated circuits and other devices, including LEDs. The wafer serves as the foundation on which the device is built. The wafer/substrate undergoes several process steps such as doping or ion implantation, etching, deposition of various materials, and photolithographic patterning. Finally, the individual microcircuits or dies are separated through dicing and go through the packaging process.

Wafers are formed from highly pure single crystalline material. One process for forming crystalline wafers known as Czochralski growth was invented by the Polish chemist Jan Czochralski. In this process, a cylindrical ingot of high-purity monocrystalline semiconductor, such as silicon or germanium, is formed by pulling a seed crystal from a `melt'. The melt is slowly cooled to the required temperature, and crystal growth begins around the seed.

As the growth continues, the seed is slowly extracted or 'pulled' from the melt. As the ingot is pulled, it is slowly rotated. This is done to normalise any temperature variations in the melt. This is a complex, proprietary process requiring many control features on the crystal-growing equipment and this is common process in growing silicon wafer/substrate.

The process of growing some other types of substrates such as sapphire, GaN, SiC, and GaAs might be slightly different, but the basic concept is still the same. Once the wafer or substrate has been completed, only then can devices such as integrated circuits and LEDs can be fabricated on the wafer. This chapter will provide an overview the technologies behind the substrate manufacturing, LED device and MMIC fabrication. This will be followed by the outlook of the compound semiconductor global market (focusing on those three subsectors) and finally a discussion of Malaysia's position in the compound semiconductor industries as well as how Malaysia can become a in this rapidly growing sector.

1.1.2 SUBSTRATE MANUFACTURING

Substrate manufacturing involves the process of growing semiconductor materials to be the substrate or wafer that will be used for device fabrication. The most widely used material for substrate is silicon due to the high demand in microelectronics products such as microprocessors, signal processors and analogue circuits. However, the demand for high performance circuits and applications has led to the big efforts in finding better materials. This is how, compound semiconductors are born. Fabrication of devices using compound semiconductor materials need wafer or substrates.

For this purpose, several materials have been used or at least investigated to be the best candidates for the substrate. Even though, silicon can also be used as the wafer for compound semiconductors, there are some limitations such as crystal matching that poses a challenge to the designers. Therefore, some other wafer materials are more popular for compound semiconductor fabrication. Among the materials for compound semiconductor are sapphire, Gallium Nitride (GaN), Silicon Carbide (SiC) and GaAs. This report will cover some of these materials.

Gallium arsenide (GaAs) has become the most-used compound semiconductor material by vol., due to its numerous applications in wireless technology. Sapphire and Silicon Carbide (SiC) have also grown in market share due to the LED market, and bulk gallium nitride (GaN) has found use in blue diode lasers. Gallium arsenide was promoted by scientists as early as the 1970s as a faster and more efficient substrate material than silicon. The most important advantage of GaAs is speed, as the electrons travel at about 8 times faster than silicon. GaAs also has high resistance to current before it is doped with impurities, leading to the semi-insulating characteristics, whereas silicon is a semi-conducting material. Another major advantage of GaAs is that it can be doped in such way as to emit light, making it useful for LED applications.

The problem with gallium arsenide is that the material is difficult to grow into large, defect-free crystals. Gallium is not found naturally as it diffuses into many other substances and is only can be obtained by melting of a substance. The process to acquire a pure gallium begins with melting other materials/substances to find Ga. Next, the Ga ingot is made and purified further before it can be used as a semiconductor substrate. Gallium's melting point is about 30ºC and must be handled carefully so that it does not melt and diffuse in its container.

Another constraint is the solid gallium is quite brittle so it complicates handling. Arsenic itself is very toxic and needs to be handled delicately. In other words, both of the materials for a GaAs wafer are quite complicated in terms of handling. In the compound form, GaAs is also brittle and wafers are normally limited to a 4-6 inch diameter, compared to silicon's 12 inch. This adds to the expense of a GaAs wafer. As a comparison, a 6-inch wafer of gallium arsenide costs about USD200, whereas a 200mm wafer of silicon goes for roughly USD40. This is one of the disadvantages of GaAs compound semiconductor. Meanwhile, Sapphire is interesting due to high hardness and strength, transparency in the visible and infrared spectrum, good thermal conductivity, and thermal shock resistance and high melting point. LEDs are the largest market for sapphire use. LED applications include backlighting of LCD displays, as well as automotive and other lighting needs.

Furthermore, sapphire is a crystal grown using single crystal technology. >99.5%-pure Al2O3 (alumina) is melted higher than 2300ºC, and then slowly cooled. Its hardness and a high melting point of 2050ºC make sapphire very appropriate as a substrate for GaN, which is deposited at a high temperature. The process of making a sapphire substrate starts from raw aluminium oxide powder. This powder is processed into the intermediate crystal form required for the production of large sapphire boules. High purity alumina powder is sintered, pressed and compressed into pellets of various sizes which are designed to maximise the size of the final crystal boule for a particular furnace size. **Figure 1.2** and **1.3** depict the process of sapphire substrate manufacturing and different sizes of sapphire boules, respectively.

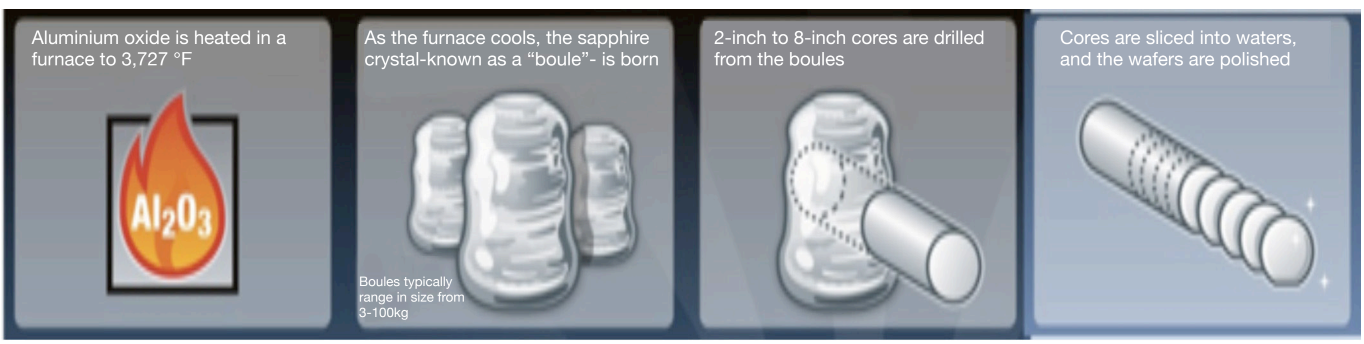


Figure 1.2 Sapphire Substrate Manufacturing Process

Source: Rubicon Technology

Figure 1.3 Sapphire Boules

Source: Rubicon Technology

Most Gallium Nitride-based LEDs or other devices begin with the fabrication of devices on sapphire substrates, Silicon Carbide (SiC), or even silicon (a process which is still under research). A majority of GaN-based devices do not use GaN as the substrate. GaN substrates offer a significant advantage for the growth of GaN-based layers, namely the much lower lattice mismatch between the layers and the substrate. However, GaN bulk crystals are difficult to grow, and commercially available GaN substrates are generally small and very expensive.

The ability to use GaN as the substrate for GaN devices, normally known as GaN-on-GaN or GaN on native GaN, will result in a device with double thermal conductivity and fewer crystal defects compared to GaN grown on other substrates. Growing GaN on a GaN substrate is one of the most active areas of research and development. The reason why other substrates being used for GaN devices is that there are no GaN ingot.

Nonetheless, if GaN is melted to the high required temperature in an attempt to grow a crystal of the material, the liquid simply dissociates into gallium and nitrogen. Apart from that, there are some GaN substrates onto which GaN is epitaxially grown. The substrates themselves are grown and sliced into wafers. Most GaN-related epitaxial growth processes are limited in thickness. GaN crystals are grown from molten Natrium or Gallium held under 100 atm pressure of N2 at 750°C. As Ga does not react with N2 below 1000 °C, the powder must be made from something more reactive, usually in one of the following ways:

$$2\ Ga + 2\ NH3 \rightarrow 2\ GaN + 3\ H2 \qquad (1)$$

$$Ga2O3 + 2\ NH3 \rightarrow 2\ GaN + 3\ H2O \qquad (2)$$

Commercially, GaN crystals can be grown using molecular beam epitaxy. This process can be further modified to reduce dislocation densities. First, an ion beam is applied to the growth surface in order to create nanoscale roughness. Then, the surface is polished. This process is carried out in a vacuum. One of the most common technologies for manufacturing gallium nitride substrates is called Hydride Vapour Phase Epitaxy (HVPE). This process begins with the heating of a substrate, typically gallium arsenide or sapphire, to around 1100°C. This is followed by wafting a mixture of gaseous compounds containing nitrogen and gallium onto its surface. The outcomes then decompose to release gallium and nitrogen atoms, which form a gallium nitride film that can be peeled off and sliced into substrates. However, researchers are currently developing methods to produce high quality GaN crystal.

1.1.3 LIGHT EMITTING DIODE (LED)

A Light-emitting Diode (LED) is a light source originating from a semiconductor such as a PN junction. In general, LEDs are just tiny light bulbs that fit easily into an electrical circuit. However, unlike ordinary incandescent bulbs or other types of filament-based general lighting, LEDs do not have a filament that will burn out or get hot. They are illuminated solely by the movement of electrons in a semiconductor material in particular, the recombination of electrons and holes from conduction bank into valence band. LEDs last just as long as a standard transistor and their lifespan surpass the short life of an incandescent bulb by thousands of hours.

Tiny LEDs are already replacing the tubes that light up LCD HDTVs (backlight) to make thinner and higher contrast display in televisions. LEDs are also used as indicator lamps in many devices and are increasingly used for general lighting. In the beginning early LEDs emitted low-intensity red light, but modern versions with

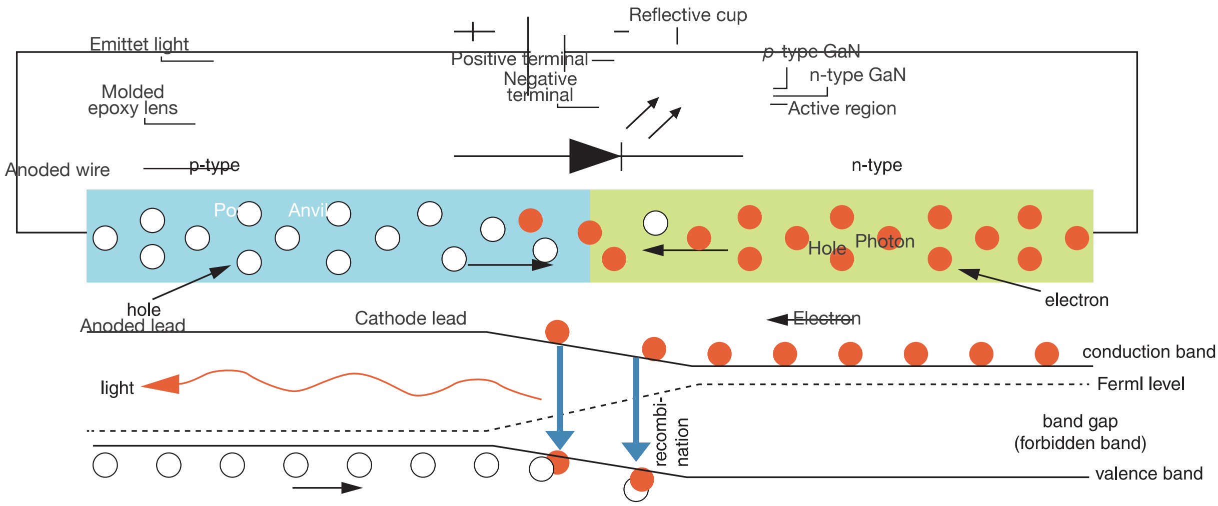


Figure 1.4 The recombination of electrons and holes emits light

several different materials and process technologies are capable of producing LEDs that emit light across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

When a light-emitting diode is switched on, electrons are able to recombine with holes within the device, releasing energy in the form of photons. This effect is called electroluminescence. The colour of the light, corresponding to the energy of the photon, is determined by the energy band gap of the semiconductor. The first commercial LEDs were used as replacements for incandescent and neon indicator lamps, and in seven-segment displays, first in expensive equipment such as laboratory and electronics test equipment and later in such appliances as TVs, radios, telephones, calculators, and even watches. Until 1968, visible and infrared LEDs were extremely costly, on the order of USD200 per unit, and so had little practical use.

The LED consists of a chip of semiconducting material doped with impurities to create a p-n junction. As in

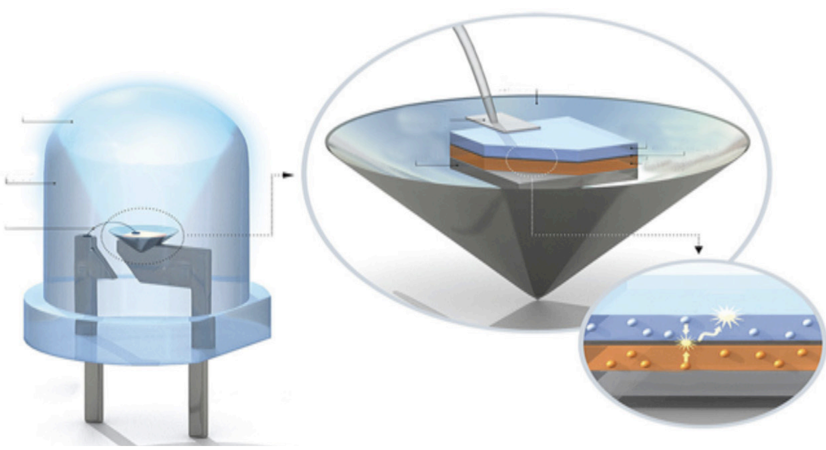


Figure 1.5 LED Structure

Source: Stevenson, IEEE Spectrum

other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level and releases energy in the form of a photon. **Figure 1.4** depicts the concept of photon energy emission from the recombination of electrons and holes in semiconductor.

The wavelength of the light emitted, and thus its colour depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes recombine by a non-radiative transition, which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible, or near-ultraviolet light.

LED development began with infrared and red devices made with gallium arsenide. Materials science advancement has allowed an increasing variety of colours due to shorter wavelengths. Such colours include red, green, yellow, blue, amber and white. The use of materials such as GaALAs (gallium aluminium arsenide), AIGaInP (aluminum gallium indium phosphide), GaN (gallium nitride) and InGaN (indium gallium nitride) allows LEDs to meet or exceed the output of typical incandescent lamps. **Figure 1.5** shows the built-up structure of an LED.

LEDs are usually made from gallium-based crystals containing one or more materials such as arsenic and phosphorus. The basic LED crystal is either gallium arsenide (GaAs) or Gallium Phosphide (GaP). The epitaxial layer is grown on the base crystal, through which a light-emitting p-n junction is formed. For instance, a p-n junction formed in an epitaxial layer of gallium arsenide phosphide (GaAsP) is grown on GaAs to produce standard red LEDs. P-n junctions in GaAsP epitaxi are grown on GaP to produce high efficiency red and yellow LEDs, while GaP epitaxi is grown on a GaP crystal to produce green LEDs.

LEDs are made by slicing the base GaAs or GaP crystals into thin wafers. An epitaxial layer of either GaAsP or GaP is grown on the wafers, and a lighting p-n junction is formed. The wafers are then divided individual LED dice, or chips, at approximately 0.010 inch (0.25mm) square in size. The GaAs or GaP crystal side of the LED chip is the cathode and the epitaxi side is the anode. The LED dice are then attached to a lead frame and packaged into individual lamps. The LED industry has seen major advancements in LED dye fabrication. Colour brightness has been greatly improved (Chicago Miniature Lighting, Technical notes).

Materials such as GaN/SiC and GaN on a sapphire substrate with wavelengths between 430 and 470mm and brightness levels of 1 to 2 candelas in lensed packages have encouraged the development of new applications for blue LEDs. They are still six times the price of standard type LEDs, but the price is dropping as production ramps up. The applications include LED signs, automotive and medical instrumentation and general indication.

Available in low-cost GaP materials with wavelengths of 555mm, green LEDs have typically been one of the lowest in brightness. After the development of GaN and AlInGaN materials with wavelengths in the 500mmrange, this colour is now one of the brightest. Through the use of low cost GaP materials to produce wavelengths of 560 to 570mm, the green industry green is most commonly used for general indication and backlighting.

Furthermore, through the use of low cost GaAsP/GaP materials to produce wavelengths of 585mm, industry yellow LEDs are used for general indication, and are the lowest in luminous intensity of all dye types. Besides that, major advancements have also transpired in the development of AlInGaP dye materials, with a wavelength of 592nm, which has taken the industry yellow colour from one of the dimmest to one of the brightest. Moreover, the price difference is about double from the GaAsP/GaP to the AlInGaP. Orange LEDs are available in low cost GaAsP/GaP at wavelengths of 605nm and highly bright AlInGaP materials with wavelengths of 610nm.

Using low-cost GaAsP materials to produce wavelengths of 630nm, industry red is still used in high volume as a general indicator, whereas very bright AlInGaP materials with wavelengths of 627nm are available for applications such as CHMSLs and rear combination lamps in the automotive industry as well as traffic signals. The AlGaS materials with wavelengths of 660nm are also available with brightness levels of 3 candelas. One of the most exciting new developments in the LED industry is the development of a single chip white LED. This is carried out by applying a phosphor coating to a blue LED dye.

1.1.4 MONOLITHIC MICROWAVE INTEGRATED CIRCUITS (MMICS)

Monolithic Microwave Integrated Circuits (MMIC) is a special type of analogue ICs which are able to process signal frequencies ranging from 1GHz to 300GHz (Robertson). The first MMICs were reported in 1968 (Mao, S, Jones & Vendelin) &(Mehal, EW & Wacker, RW), while the first transistor-based MMICs were demonstrated in 1976 (Pengelly &Turner).

In the beginning (circa 1980), MMICs were used mainly for satellite and military applications, but in the early 1990s with the development of mobile and wireless communications, gallium arsenide (GaAs) MMICs were mass-produced for the first time. Due to their relatively small size, MMICs have contributed to the miniaturization of RF and microwave circuits. Several functions can be performed by MMICs, such as mixers, gain blocks, power amplifiers, low noise amplifiers, attenuators, phase shifters, switches, VCOs, up-converters, down-converters. Added to that, single MMICs are cheap in large scale production and are most useful for applications in which small size, large quantity and medium power levels are needed (i.e. $< 10W$) (Amin K).

Substrate or wafer for MMIC must behave like a dielectric, with reasonable low losses at microwave and mm- wave frequencies. **Table 1.2** depicts different semiconductor materials for MMIC manufacturing and their important physical and electrical characteristics (Bahl, I & Bhartia, Prakash). Gallium Arsenide (GaAs) was the first material chosen for MMIC manufacturing 40 years ago due to its superior transport characteristics and low loss at microwave and mm-wave frequencies. Silicon based MMICs are however constrained to low-power applications because of high RF loss in Silicon substrate. Bipolar or Field Effect Transistors (FET) are manufactured on most semiconductors with varying degrees of difficulty. Wide band-gap compound semiconductors, such as Silicon Carbide (SiC) and Gallium Nitride (GaN), can also be used for high power and high frequency devices but these semiconductors

Table 1.2 Semiconductor materials for MMIC

MMIC Semiconductors	Electron Mobility	ε_r	RF Loss	Thermal Conductivity	Active Device Technology	Application
Gallium Arsenide (GaAs)	$0.85m^2/V/s$	12.9	Low	46 W/°C/m	MESFET, HEMT, pHEMT, HBT, mHEMT	PA, LNA, mixers, attenuators, switches, ... etc
Silicon (Si)	$0.14m^2/V/s$	11.7	High	145 W/°C/m	LDMOS, RF, CMOS, SiGe HBT (Bi-CMOS)	Mature for low power mixed signal applications
Silicon Carbide (SiC)	$0.05m^2/V/s$	10	Low	430 W/°C/m	MESFET	Very high power below 5GHz
Indium Phospide (InP)	$0.60m^2/V/s$	14	Low	68 W/°C/m	MESFET, HEMT	mm-wave
Gallium Nitride (GaN)	$0.08m^2/V/s$	8.9	Low	130 W/°C/m	HEMT	High power, limited availability

Table 1.3 MMICS application and device types

Application	Frequency	Device Process
Low Noise Amplifiers	1-10GHz	GaAs Mesfet
	10-100GHz	GaAs pHEMT
	>100GHz	InP
Medium Power	1-10GHz	GaAs HBT, GaAs Mesfet
	10-100GHz	pHEMT
High Power	1-10GHz	GaAs Mesfet, GaN, SiC
	10-30GHz	GaN
Switches for digital attenuators and phase shifters	0.1-20GHz	Mesfet
	20-100GHz	pHEMT
Low Noise Amplifiers	1-50GHz	SiGe BiCMOS
VCO	1-100GHz	GaAs HBT

are expensive. Silicon Carbide (SiC) is used for high power but is limited to below 5GHz applications (Mattias, S*et. al*) and Gallium Nitride (GaN) is promising to push the power limit of MMICs at microwave and mm-wave frequencies. Though GaN-based devices have received a great deal of attention due to their characteristics, but low cost GaN MMICs are not available yet due to high cost.

Active devices used in MMIC applications are mainly FET or bipolar types. Several FET types being developed using GaAs include Metal-Semiconductor Field Effect Transistor (MESFET), the High-Electron Mobility Transistor (HEMT) and the Pseudomorphic High-Electron Mobility Transistor (PHEMT). Examples of bipolar transistors types include the SiGe Heterojunction Bipolar Transistor (HBT) and the GaAs HBT. GaN and SiC based MMICs usually use MESFET or HEMT device structures. **Table 1.3** shows some of the MMICs application and their transistor types.

1.2 GLOBAL MARKET AND DRIVERS FOR COMPOUND SEMICONDUCTOR

Silicon still dominates the semiconductor industry as a standard material, with gallium arsenide (GaAs), indium phosphide (InP), gallium phosphide (GaP), gallium nitride (GaN), silicon carbide (SiC), and sapphire substrates currently accounting for just 1.1% of the 7504 million square inches processed annually in semiconductor foundries.

However, specific applications such as optoelectronics, RF wireless and power electronics require device performance (i.e. frequency, power, thermal conductivity, robustness, junction temperature, voltage breakdown and so on) that is not reachable by using the material properties of silicon, so compound semiconductor materials have been protected from competition from silicon. Hence, though compound materials have much higher market prices than silicon, their technical specifications have been and remain the main driver for the adoption of compound semiconductor substrates and related technologies.

Nonetheless, all the mentioned compound semiconductor materials are now available in wafers of 4 inches in diameter, except for bulk GaN, which has just been launched in 3-inch form in Japan. This increase in the diameter of wafers helps lower the cost of manufacturing devices and makes mass-market products affordable, boosting the market for compound semiconductor substrates [Yole Développement]. The proportion of compound semiconductor substrates used (compared to silicon) is expected to continue to grow (from 0.56% in 2006 to 0.62% in 2007) with consistent growth to 0.84% shown in 2012 per **Figure 1.6**.

Driven by demand for wireless technology, gallium arsenide (GaAs) has been the most-used compound semiconductor material in terms of volume. Moreover, sapphire and silicon carbide (SiC) have benefited from the booming LED market, while bulk gallium nitride (GaN) has become essential for blue laser diode makers [Yole Développement]

The GaAs substrate market is expected to increase at a compound annual growth rate (CAGR) of nearly 11% to more than $650m by 2017, as shown in **Figure 1.7**. This market expansion is fuelled primarily by rising GaAs content in handsets and rising penetration of LEDs in general lighting and automotive applications.

MMICs (power amplifiers, switches etc.) are initially comprised of the main market for GaAs wafers and will continue to fuel the business in the coming years due to the development of sophisticated smartphones, the development of 3G/4G networks, and the increased demand for data communications. Added to that, recently, the development of new GaAs-based devices are enhancing the market with associated high-volume applications such as LEDs, which are currently booming due to their advantages over traditional light sources. Furthermore, other devices, such as solar cells for high-concentration photovoltaics (HCPV), will also increase the development of the GaAs substrate market, but to a

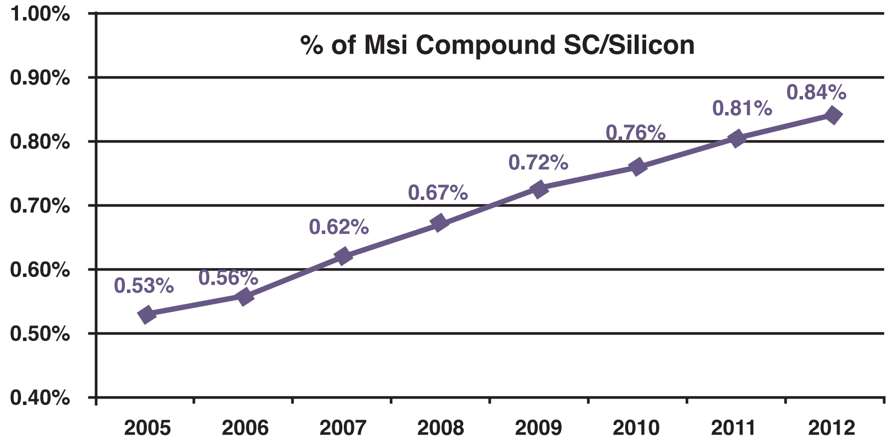


Figure 1.6 Percentage of compound semiconductor substrate compared to silicon

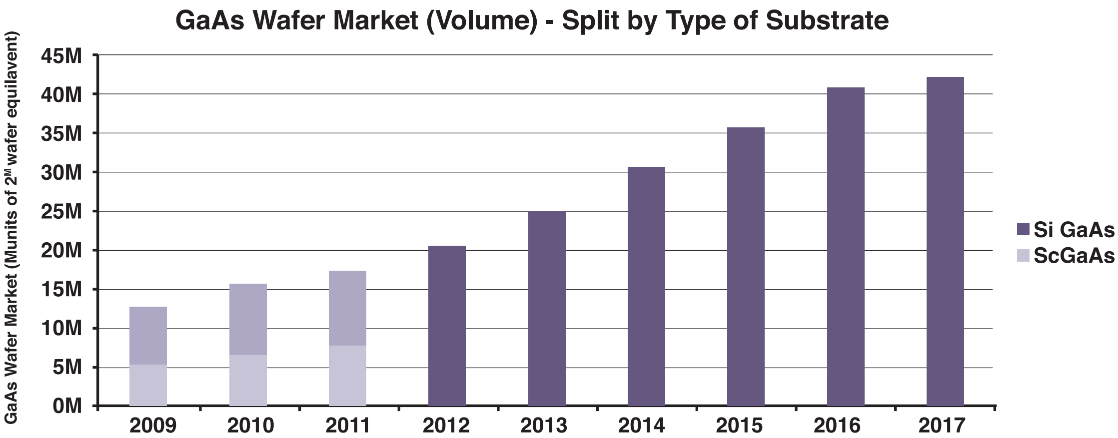


Figure 1.7 GaAs Wafer Market Trend

lesser degree (Yole Développement). **Figure 1.8** shows applications and markets for GaAs devices.

Sapphire has emerged as a versatile material useful to a range of industries in many applications including LEDs, optics, and RFICs. Sapphire has a number of attributes that make it suitable for a wide range of end markets, including its hardness and resistance to physical damage and chemical erosion.

LEDs are the largest market for sapphire substrate. In LED market, the major end applications are general lighting and LCD backlighting. Other noteworthy LED market include signage and automotive. However, the advantages of sapphire vary by application. For example, lighting and industrial and automotive applications benefit more from long life compared to mobile handsets and notebooks, which prioritize high brightness and low power consumption. **Figure 2.9** shows the demand forecast of the sapphire ingot for LED application.

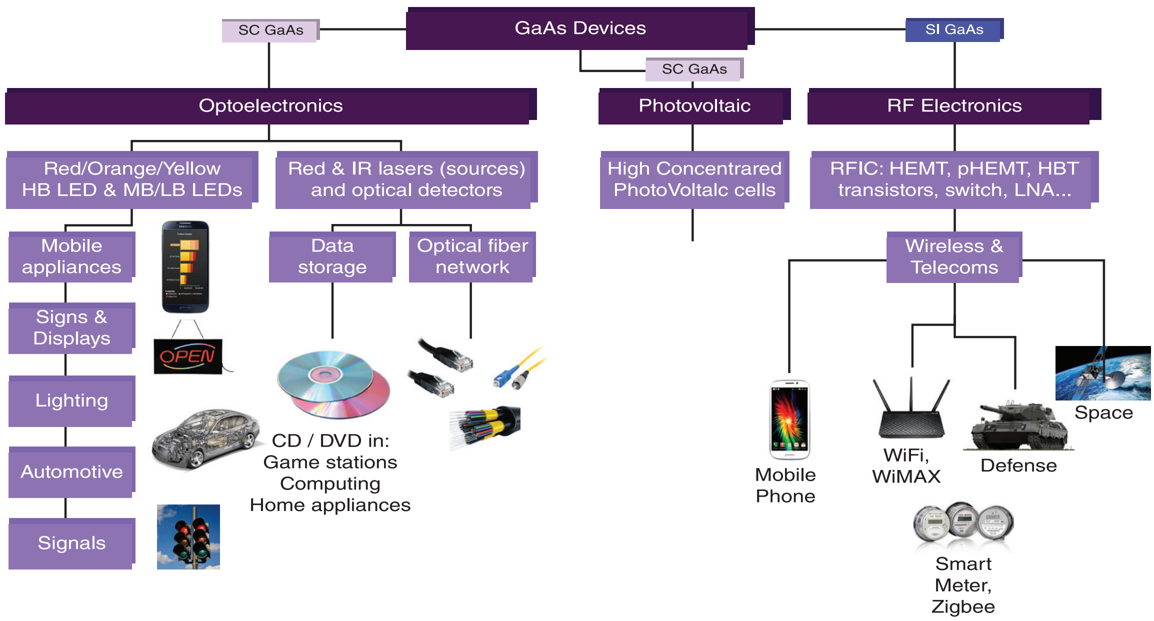


Figure 1.8 GaAs markets and applications

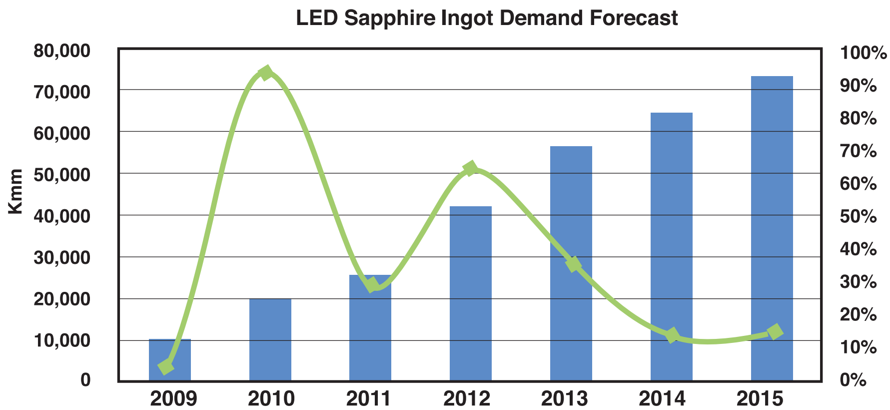


Figure 1.9 sapphire ingot demand forecast

Driven by the booming business in white LEDs for LCD backlights and general illumination, sapphire was expected to become the leading compound Density g/cm Linear Coeffcient of Thermal Expansion *10 semiconductor substrate material in terms of volume by 2011. This exceeds 50% of the total of total compound semiconductor processed surface area [Yole Développement, Report on Compound Semiconductor Substrates 2010].

The market for gallium nitride (GaN) devices include two primary sectors, namely LEDs, in which GaN enables much higher efficiency in green, blue and ultraviolet applications, and communication devices, in which power and linearity are most important. GaN has been used in LEDs for some years, but high-volume. application is just beginning. Two of the most important applications are in mobile telephone base stations and military radar systems. The military appreciates the important part that GaN may play in X-band radar systems. This is a high-end application area that GaN should excel in.

Although the need for GaN devices has spurred research and development, the vol. of GaN devices being sold into all markets is expected to amount to no more than a small fraction of the vol. of GaAs devices sold within the next few years. While GaN is intriguing, many more mobile phone handsets and satellite television receivers use GaAs chips. One active area of research and development into GaN is the matter of native substrates for GaN. At least six different substrate materials are currently used experimentally (and often commercially), for GaN. The reason for such a diversity of substrates is that there no GaN ingots exist such as those of silicon.

Currently, the native substrates in use for GaN, for both LED and high-frequency, high power applications are bulk GaN, diamond, silicon carbide, sapphire, aluminium nitride, and silicon. The most important considerations for the selection of the substrate type for a given application include the degree of lattice mismatch between the active GaN layer and the substrate, the thermal conductivity of the substrate, the difference in coefficient of thermal expansion between the substrate and the epitaxial layer, and the overall cost of the substrate. **Table 1.4** shows some of the substrates used for GaN as well as their characteristics.

	Density g/cm^3	Linear Coefficient of Thermal Expansion $*10^{-6}/K°$
GaN	6.1	5.59
Diamond	3.52	1.18
SiC	3.22	10.3
Silicon	2.6	2.33

Native bulk GaN has emerged as an alternative to sapphire or silicon, allowing further improvement of LED performance. Despite potential performance benefits for ultra-high brightness (UHB) LEDs, massive adoption of GaN wafers remains hypothetical. Taking into account the historical price reductions of bulk GaN substrates, a base scenario outlines where the GaN on GaN LEDs will be limited only to niche markets. If the GaN industry succeeds in replying to the cost pressure from LED makers and the price of 4 inch GaN wafers falls below the breakeven price, a more significant adoption is forecasted. [Yole Développement]. Combining all applications, the demand for 2” GaN substrates will be more than two times higher in an aggressive scenario than in the base scenario. In the best case, the demand will remain relatively stable until 2020.

In MMIC applications, Bulk GaN substrates present a very challenging scenario. The GaN power device industry (MMIC) generated less than USD2.5M in revenues in 2012. However, overall GaN activity has generated extra revenues as R&D contracts, qualification tests, and sampling for qualified customers was extremely buoyant. 16 out of 20 established power electronics companies are involved in or will be involved in the GaN power industry.

Among the numerous substrates proposed for GaN power devices, bulk GaN solution is definitely beneficial to the device performance. However, Yole Développement remains quite pessimistic that bulk GaN could widely penetrate the power electronics segment unless 4” bulk GaN wafers can be in the USD1,500 range by 2020. The main reason is that, GaN power devices are positioned as a cost-effective solution, between incumbent Silicon and the ramping-up SiC technologies. If that $1,500 cost cannot be reached, then no bulk GaN substrate will penetrate the market (Yole Développement).

1.3 GLOBAL PLAYER – A CASE STUDY

1.3.1 SUBSTRATE MANUFACTURER

Sapphire is one of the popular substrates for LEDs and MMICs. There are more than 130 companies working/are involved in sapphire substrate. About 50% of these are from China. However, only 10 companies have captured more than 70% market shares. This means that there are only a few big players in sapphire substrate. **Figure 2.10** shows countries that involved in sapphire wafers manufacturing.

Rubicon Technology based in USA is one of the big players in sapphire substrate that is engaged in developing, manufacturing and selling monocrystalline sapphire and other crystalline products for light-emitting diodes (LEDs), radio frequency integrated circuits (RFICs), blue laser diodes, optoelectronics and other optical applications. The company applies its proprietary crystal growth technology to produce very high-quality sapphire in a form allowing for vol. production of various sizes and orientations of substrates and windows. The Company is actively developing larger diameter products to support next-generation LED, RFIC and optical window applications. In 2010, Rubicon Technology opened a new State of the art polishing factory in Malaysia. Previously, polishing had been deemed as a back-end process in the substrate manufacturing value chain. All front-end processes in sapphire substrate manufacturing by Rubicon Technology are done in USA.

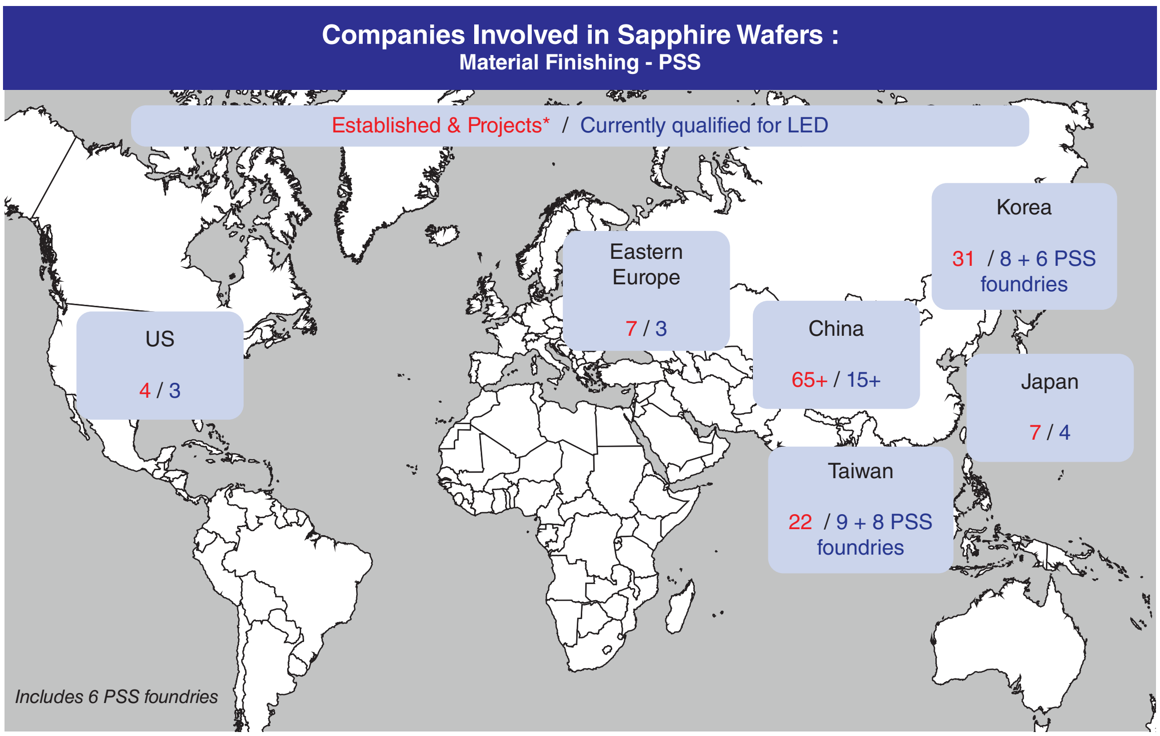


Figure 1.10 Sapphire substrate manufacturing players based on country

For another widely used substrate, GaN, 87% of the market is heavily contested by Japanese companies. Currently, non-Japanese players are in the small vol. production or R&D stages; which is too early to challenge the market leaders. Japan will continue to dominate the Bulk/FS GaN market for the coming years. **Table 1.5** indicates some of the players from different countries for GaN substrates.

Table 1.5 GAN substrate global players

	Japan	China	US	Europe
Players	Sumitomo Hitachi Metals Mitsubishi Chemical NGK Insulators Furukawa AETech	Sino Nitride Semiconductor Nanowin PAM Xiamen	UCSB Soraa Kyma Sixpoint Materials Goldneye	Ammono SaintGobain/ Lumilog Unipress Freiberger

1.3.2 LED BUSINESS PLAYER

Three of the biggest players in LED manufacturing are CREE, Lumileds and OSRAM. All of their higher value chain or front-end operations are located at USA, Netherland and Germany while the back-end operations are located in various part of Asia. **Figure 1.11** to **1.13** show the location of various operation stages for the three big players in LED manufacturing (Yole Developpement).

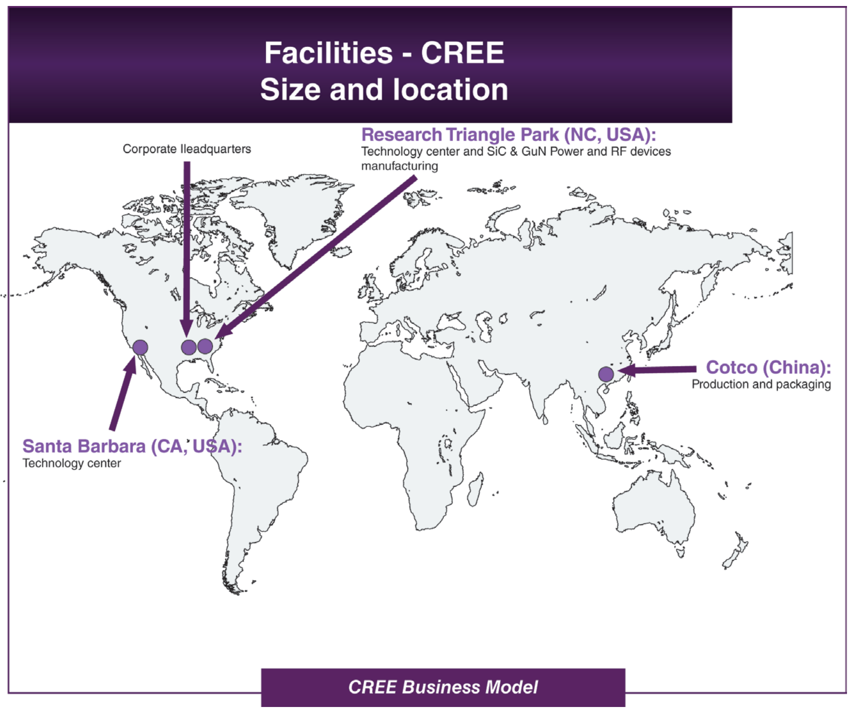


Figure 1.11 CREE LED manufacturing facilities

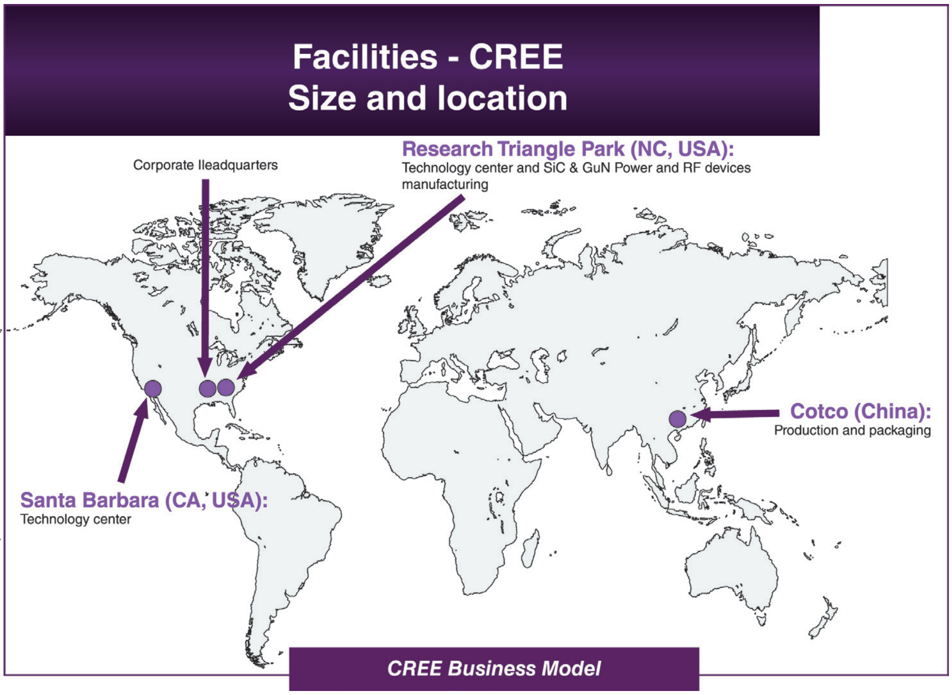


Figure 1.12 Lumileds LED manufacturing facilities

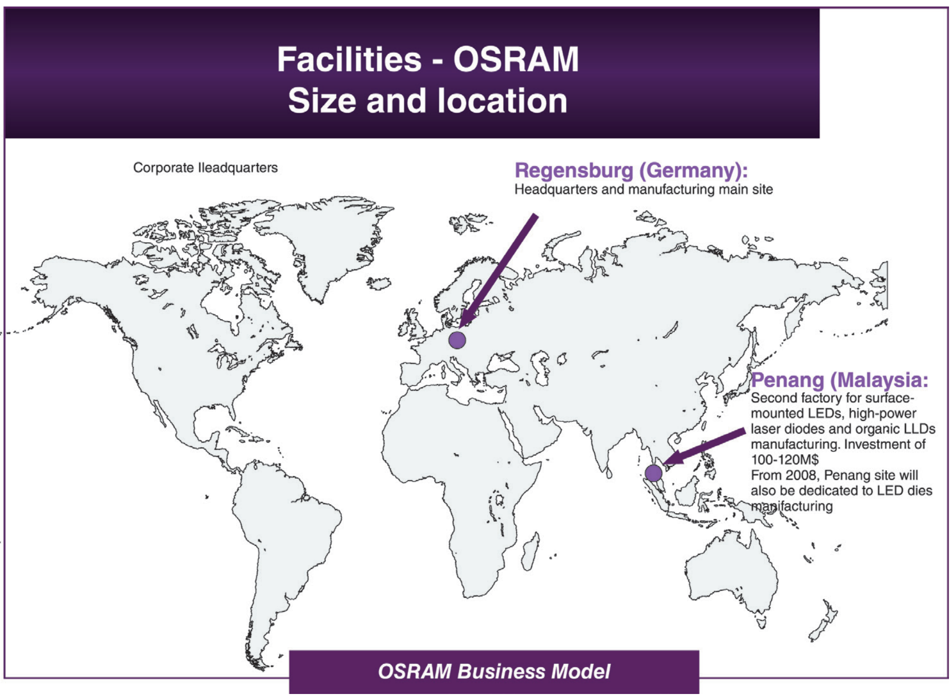


Figure 1.13 Osram LED manufacturing facilities

1.3.3 MONOLITHIC MICROWAVE INTEGRATED CIRCUIT (MMIC) INDUSTRY PLAYERS

Setting up a MMIC fabrication facility or foundry for mass production is prohibitively expensive (Robertson, ID&Lucyszyn, S). At one time, most major microwave companies had their own facilities. When the profits were not forthcoming, several of these companies regrouped and underwent consolidation. There are still more than 35 foundries of GaAs MMICs and the number of companies for silicon RFICs and MMICs are growing rapidly.

Table 1.6 List of MMIC Foundries

Foundry	Location	Capabilities	Processes offered	Market
Cree	Durham, NC, USA	3" SiC & GaN	GaN HEMT & SiC Mesfet	Offers SiC foundry services & has a product line
Filtronics Compound Semiconductors	Santa Clara, CA, USA	6" GaAs	0.2μm pHEMT	Offers foundry services & has a product line
GGS	Torrance, CA, USA	6" GaAs	0.5μm pHEMT, InGap & HBT	Only offer foundry services
IBM	Burlington, VT, USA	Silicon	0.18μm, 0.25μm, 0.35μm, 0.5μm, SiGe BiCMOS & 0.13μm, 0.18μm, 0.25μm RFCMOS	Only offer foundry services
Knowledge ON	Iksan, S. Korea	6" GaAs	InGaP HBT	Offers foundry services & has a product line
M/A ON	Lowell, MA & Roanoke, VA, USA	4" GaAs	0.18μm, 0.5μm & 1μm, pHEMT, 0.5μm & 0.35μm, Mesfet MSAG	Offers foundry services & has a product line
Nitronex	Raleigh, NC, USA	GaN on 4" Silicon	GaN HEMT	Offers new foundry services & has a product line
SiGe Semiconductor	Ottawa, Ontario, Canada	SiGe	SiGe BiCMOS	Offers foundry services & has a product line
Transcom	Tainan, Taiwan	6" GaAs	0.15μm, 0.25μm pHEMT and 2μm HBT	Offers foundry services & has a product line
Triquint Semiconductor	Portland, OR, & Dallas, TX, USA	6" GaAs & GaN	0.25μm, 0.5μm & 13μm, 0.25μm, 0.35μm, 0.5μm,pHEMT, 0.5μm & 0.6μm Mesfet, 0.5μm HFET, 3μm InGaP HBT	Offers foundry services & has a product line
United Monolothic Semiconductor	Ulm, Germany Orsay, France	4" GaAs	0.15μm, 0.5μm pHEMT and HBT	Offers foundry services & has a product line
WIN Semiconductor	Tao Yuan Shien, Taiwan	6" GaAs	0.15μm, 0.5μm pHEMT and 1μm, 2μm HBT	Only foundry services

MMIC manufacturing services are offered by many foundries in the USA, Europe and the Far East. A foundry process is typically defined by both the type of active device and the device's smallest dimensional feature such as gate length in FET devices or the emitter width in bipolar devices. **Table 2.6** lists most of the commercially available MMIC foundries worldwide. Some other foundries which are not listed in the table are either R&D facilities or offer manufacturing capabilities only to internal corporate customers or for their own line of products. Only Gallium Arsenide (GaAs) and Silicon foundries are available for large scale MMIC production, while other semiconductors are used in research labs or in small foundries which are primarily working on research and advancing the State-of-the-art.

When MMIC technology was developed through government funded research from the mid-1980s to the mid-1990s, MMIC manufacturers maintained small facilities. However, today the most successful foundries are much larger. It has been estimated that a new MMIC foundry requires investment of at least $200 - $500 million. In selecting a foundry process, the cost per mm2 of wafer is the driving factor to remaining competitive.

For this reason many foundries are upgrading their equipment to 6" GaAs wafers to lower the cost to their customers. The cost of a MMIC chip is very low and ranges from $0.20 to $3.0 per mm2 depending on the size of the chip and the process used in manufacturing. SiGe MMICs are the least expensive, while 0.15μm pHEMT, GaN HEMT and SiC Mesfet are the most expensive. Nevertheless, MMIC development is costly and time consuming; the cost of a foundry run can vary from $40,000 to $100,000 depending on process type, number of wafers requested, and any post fabrication steps requested, such as on-wafer testing or pick-and-place. The cost typically includes a complete set of masks (usually 8 to 15 layers) and 2 to 6 diced wafers ready for pick and place.

1.4 MALAYSIA'S POSITION IN COMPOUND SEMICONDUCTOR INDUSTRY

1.4.1 SUBSTRATE MANUFACTURING

Substrate manufacturing is a capital-intensive industry that requires a large budget and high-skilled human resources. The worldwide semiconductor market (not specific to compound semiconductors) is currently valued at RM812 billion (2009) and is expected to grow at about 7% per year. The output value of semiconductors in Malaysia is around RM39 billion (2009), a global share of 5%. However, a majority of the semiconductor market in Malaysia is predominantly focused in Silicon-based products, and the semiconductor firms operating in Malaysia concentrate primarily on assembly and testing. Furthermore, while there are several foreign companies operating in Malaysia for silicon wafer manufacturing, such as Sumitomo and Shin-Etsu, this is not the case for compound semiconductors.

Malaysia's role in front-end substrate manufacturing (other than silicon) either through foreign or local companies is still non-existent. In 2010, Rubicon technology opened a State-of-the-art facility responsible for the labour-intensive crystal polishing process for

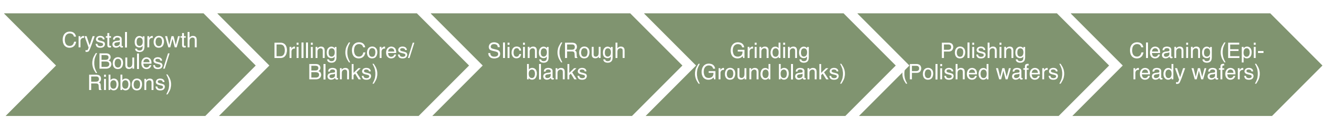


Figure 1.14 Substrate manufacturing value chain

wafer production. Polishing is a back-end process in the substrate manufacturing value chain. **Figure 1.14** shows the value chain for substrate manufacturing.

1.4.2 LIGHT EMITTING DIODE (LED)

IN terms of LED products, Malaysia currently exports RM 1.8 billion (2008 data) of LEDs, which represents approximately 10% of the global LED market, with most of these exports in the illumination (luminaire) sector. Solid State lighting is one of the fastest growing sub-segments, projected to grow at 28% per annum over the next 10 years, to a size of RM170 billion (Economic Transformation Programme – A roadmap for Malaysia)

Currently, four of the largest global SSL companies either operate in or control a significant portion of companies in Malaysia. There are also a number of companies involved in other areas of SSL such as contract manufacturing, systems integration, LED packaging, and application design, as well as speciality companies focused on various heating and optical elements.

1.4.3 MONOLITHIC MICROWAVE INTEGRATED CIRCUIT (MMIC)

Setting up a MMIC fabrication facility for mass production is an expensive investment prospect. Other than expensive fabrication equipment, another major investment required is in CAD facilities. The task of designing a competitively priced circuit should not be underestimated and extensive CAD facilities along with experienced designers are essential. While there are several small scale R&D based compound semiconductor fabrication facilities in Malaysia, there is no commercial compound semiconductor foundry in Malaysia.

1.5 COUNTRY POLICY

1.5.1 MALAYSIA'S LED INDUSTRY ROADMAP

In 2009, the Malaysian government launched the National Green Technology Policy to move toward a low carbon economy and achieve sustainable development after the worldwide energy crisis and the global financial meltdown of 2007-2008. Through this policy, a Green Technology Financing Scheme (GTFS), amounting to about USD494.97 million (RM1.5 billion) was established that was available to manufacturers of green products and developers using green technology.

These government efforts have supported and sustained the continuous growth of Malaysia's LED industry. In addition, Malaysia ceased all production, import, and sale of incandescent light bulbs by January 2014 as part of an efforts to save power and cut greenhouse-gas emissions. Currently, fewer than 5% of lights in Malaysia are LEDs, providing LED companies with an untapped domestic market.

1.5.2 ECONOMY TRANSFORMATION PROGRAMME (ETP)

Another government initiative, the Economic Transformation Programme (ETP), aims to utilise Malaysia's economic sectors to propel the country into a high-income nation. The programme details 15 Entry Point Projects (EPPs); specific to Malaysia's semiconductor, solar, LED, industrial electronics, and home appliances sectors. The EPP for the LED sector focuses on the following:

- To attract more substrate and epitaxy manufacturers to complete the solid-State lighting (SSL) value chain in the country;
- To build more LED wafer fabrication plants to further develop the country's LED cluster; and
- To aggressively cultivate Malaysia's strong position as a packaging hub for SSL products.

The programme also plans to develop at least five Malaysian companies into regional and global brands for SSL products and/or components by 2020. The goal is to have at least one local SSL company become a globally recognised name in the SSL market each year from 2012 to 2016.

1.5.3 THE CHALLENGES

Cost is a major issue in the growth of the market. The worldwide LED chip market is dominated by big companies such as Osram, Nichia Corporation., and Cree Inc. Initial investment in this sector is high and countries such as Germany, Japan, and the US are far ahead technology-wise compared to Malaysia. Nevertheless, in Malaysia, a majority of the LED players are focused on LED packaging. To produce LED modules, a company must invest in machinery and quality materials.

According to Razali Mohammed, CEO of the MyLED Group, in order to build LEDs, 70% of the machinery should be built in-house. "Our automation machine costs USD2.65-3.31 million (RM8-10 million) for one LED assembly line alone," Mohammed said. MyLED Group is a local company that has both SSL and LED manufacturing technology. The firm has invested UD54.90 million (RM175 million) to expand its manufacturing capability in the green technology sector.

Another factor that adds to the costs of LED production is the lack of availability of raw and quality intermediate materials. Most of the materials used to produce LED modules such as the wafers, ceramic substrates and silicon are imported. Although some of the materials may be available locally, a number of LED packaging firms still import materials in order to meet quality requirements. To illustrate, Osram is the only company that has its own wafer fabrication facility Malaysia. Manufacturers in Malaysia are still dependent on imported chips for producing quality modules.

1.6 CONCLUSION

Compound semiconductors are an emerging industry which has recently seen tremendous growth. This has been driven by the booming smartphone industry and increasing demand for LED applications. Currently, LED devices are widely used in different type of applications such as mobile phones, display devices, and the automotive industry, and will continue to grow in the near future with increase LED lighting application to replace conventional filament and incandescent-based lights. The reason for this is simple. Solid State LEDs are versatile, with strong integration capabilities due to small size and minimal power consumption.

Globally, many companies are working and participate in the compound semiconductors. However, significant market share is held by big players from Europe and the United States. This chapter has presented the fundamental basis of the industry in terms of the technology and drivers; hence, it will serve as a good starting point for ventures in this competitive industry.

CHAPTER 2

COMPOUND SEMICONDUCTOR: MOVING UP THE TECHNOLOGY VALUE CHAIN

The Electronics and Electrical sector is an important contributor to Malaysia's economy, accounting in 2009 for 6% of Malaysia's gross national income (GNI), 522,000 jobs, and 41% of Malaysia's total exports [ETP, chapter 11]. The E&E industry has also played a major role in the development of the Northern Corridor (semiconductors and industrial electronics), Klang Valley (sophisticated services), Johor (logistics intensive E&E manufacturing) and Sarawak (developing cluster for silicon substrate manufacturing).

Malaysian E&E has a strong foundation in semiconductors and industrial electronics. Moreover, there are some emerging sectors growing globally at more than 20% a year, such as solar photovoltaic technology (solar) and light emitting diodes (LEDs). Malaysia already enjoys a strong base of companies and is poised to capture global growth in manufacturing capacity.

Malaysia's focus on E&E, especially in the semiconductor, LED and IC industries, has traditionally been on assembly or other lower value-added segments of the industry. Meanwhile while countries like Taiwan, South Korea and Singapore have captured the higher value-added activities in R&D, design and manufacturing. Hence, it is crucial for Malaysia to move up the value chain while maintaining the current back-end segments. The idea is to have the most coverage along the total value chain in a particular industry. This will not only provide a stronger contribution to the country's economy along with the entailed job opportunities, but will also provide an opportunity for Malaysia to contribute in the emerging technology by capitalising on its abundant natural resources.

2.1 MOVING UP THE VALUE CHAIN: CONCEPTUAL FRAMEWORK

According to World Bank report, "Moving up the value chain concerns the process of shifting productive activity of a nation, an industry or a firm towards the production of goods and services that generate higher value added. While at the surface this might come across as a fairly straight-forward process, moving up the value chain is an inherently complex undertaking. It requires a fundamental shift in the sources of growth and competitiveness. To move up the value chain, competitiveness can no longer be measured merely in terms of the volume of goods and services that can be produced at the lowest possible cost. Instead, it needs to be measured by the amount of domestic value added that can be generated by globally competitive firms operating in Malaysia."

However, the proposition made in this mega science framework, in particular the electrical and electronic sectors, is not entirely in agreement with the World Bank report; instead, moving value chain should not only be measured by the amount of domestic value added generated by global firms operating in Malaysia, but also the amount of domestic value added generated by local Malaysian companies. It is a roadmap for domestic local companies in Malaysia take part in the higher value-added business. Although, it is good for the global firms to bring higher-value chain to Malaysia, greater emphasis should be placed on setting up local firms that play a bigger role in the front-end of the industries.

2.1.1 THE NEED AND URGENCY TO MOVE-UP THE VALUE CHAIN

Moving up the value chain is central to Malaysia's aspiration of joining the league of high-income economies. Malaysia seems stuck in a middle-income trap, a predicament which prevents middle-income countries from taking the next step on the development path towards high income. This has manifested itself in the growing inability to remain competitive as a high-vol., low-cost produce coupled with the difficulty to break into fast-growing markets for knowledge-and innovation-based products and services. The implication is that, despite past growth successes, living standards measured by per capita gross national income could have been significantly higher (World Bank report).

The electrical and electronic sector is an important contributor to Malaysia's economy, with exports in the range of RM250 billion in 2008. It employs more than half a million people, many in better-paid skilled positions. With about 1,900 active companies, the sector has seen many success stories, especially in the fields of semiconductors and industrial electronics. Malaysia is home to many of the largest and most successful companies in the field such as Rubicon, OSRAM, Lumileds, and Agilent, and has incubated home-grown stars like Silterra and several research and development centres for compound semiconductors. It has seen a strong start in the fast-growing subsectors of solar and light emitting diodes.

As such, there are faced by in several challenges for Malaysia increasing the need to move-up the value chain include (ETP Roadmap) such as the following:

E&E's contribution to Malaysia's exports and its economy has in decline.

E&E's share of Malaysian exports increased dramatically during the 1970s and 1980s as Malaysia industrialised and introduced enabling policies, such as free trade zones. However, since 2000, E&E exports have grown more slowly than other exports (at 0.4% for E&E versus 7% for all exports), resulting in a decline in its share of exports from 59% in 2000 to 41% in 2009.

Malaysia's E&E sector is facing increasing competition.

China, which has emerged as the world's factory, is a significant threat. A World Bank study shows the increase in export competition between Malaysia and China [World Bank 2009]. In 2007, 59% of Malaysia's exports to EU were under threat from China, compared to only about 31% in 1990. Other emerging Asian economies such as Vietnam are fast developing low-cost companies in the E&E industry; while at the high-end, Singapore and Taiwan compete for investments in higher-value added activity.

***Concentration of activity in assembly results in lower value-added gains*.**

While Malaysia has built up significant clusters in E&E, much of the activity is in relatively low value-added assembly, rather than higher value-added activities such as component manufacturing or R&D. For instance, for Penang, with its semiconductor cluster, most of the activities are on assembly and testing rather than higher value wafer fabrication. As a result, the value added per worker of about RM70 thousand is comparable to that of China and only a fifth of Singapore's.

2.2 MALAYSIA'S STANDING IN THE GLOBAL COMPOUND SEMICONDUCTOR INDUSTRIES

In this section, the value chain for substrate manufacturing, Light Emitting Diode (LED) and Monolithic Microwave Integrated Circuit (MMIC) will be explored, and opportunities that can be taken by Malaysia as well as their economy contribution will be proposed.

2.2.1 SUBSTRATE MANUFACTURING

The substrate manufacturing industry involves several capital intensive sectors that focus on growing semiconductor material that can be made as the wafer or substrate for compound semiconductor devices. The value chain starts with crystal growth activity of the said semiconductor material. Once the crystal is ready, several activities or processing are carried out, including drilling, slicing, grinding, polishing and cleaning. **Figure 2.1** depicts the value chain of the substrate manufacturing industry.

Figure 2.1 Substrate manufacturing value chain

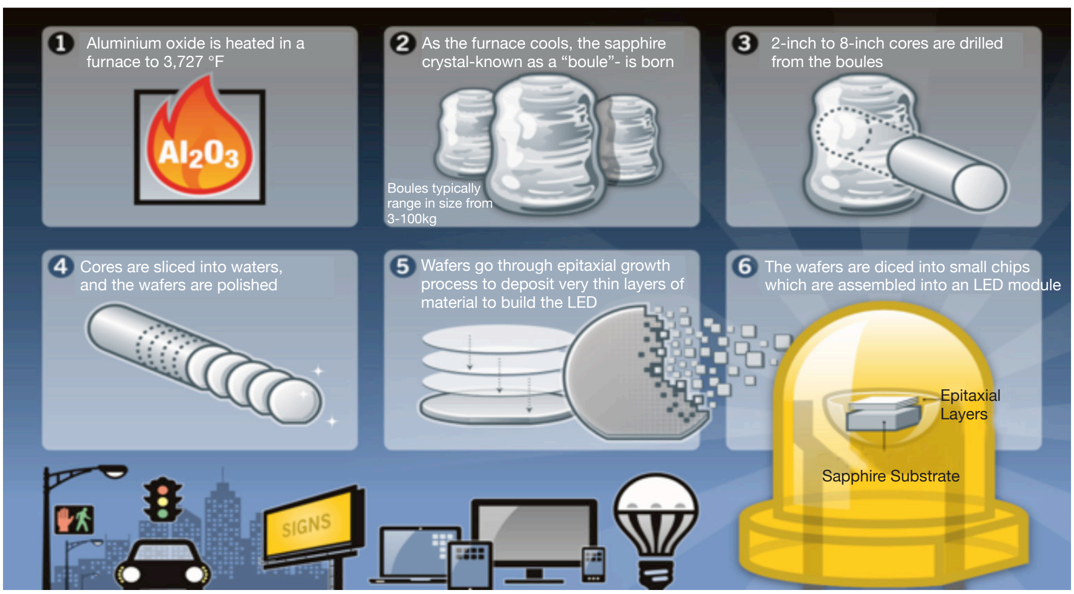


Figure 2.2 Sapphire substrate manufacturing

Source: Rubicon Technology

For instance, **Figure 2.2** illustrates all the processing steps involve in sapphire substrate manufacturing, per an infographic from Rubicon Technology. In this Figure, the process steps for the substrate/wafer making are until step 4. Steps 5 and 6 are the processes involve in LED device manufacturing.

2.2.1.1OPPORTUNITIES

The raw material for sapphire substrate is aluminium oxide (Al_2O_3). Aluminum oxide is produced industrially from the mineral bauxite. Bauxite deposits worldwide are estimated at approximately 20 billion tons, while annual worldwide output amounts to about 100 million tons. Australia has the largest output and deposit levels. Aluminum and aluminum oxide are manufactured using the Bayer method. Bauxite is crushed, dried, and dissolved using concentrated sodium hydroxide solution. Impurities such as iron, silicon, and titanium are separated from the bauxite in so-called red mud. Aluminum hydroxide is precipitated from the solution and calcinated at 1200-1300 °C to form Al_2O_3.

Fine aluminium oxide powder or commonly known as alumina powder is added to an oxyhydrogen flame and this is directed downward against a mantle (Heaton). The alumina in the flame is slowly deposited, creating a teardrop shaped 'boule' of sapphire material (step 2 in **Figure 2.2**). Once the single crystal sapphire boules are grown they are cored-drilled into cylindrical pieces (step 3). Wafers are then sliced from these cylindrical cores (step 4).

Currently, Malaysia's status in this value chain, especially related to sapphire substrate manufacturing, is at the lower-end (polishing and cleaning). One of the global players thathave established a plant for this purpose is Rubicon Technology. The front-part is handled by the USA headquarters and the lower-end is by Rubicon Malaysia. Looking at the value chain for substrate manufacturing, at least two different local companies can be created to cover the complete value chain. One company can work on the front end (crystal growing and ingot/boule production) and another company on the lower-end (drilling, slicing, and wafer polishing)

Malaysia produces bauxite mineral (British Geological Survey). In 2007, Malaysia produced 156,785 tonnes of bauxite; by 2009 the amount was up to 280 thousand tonnes, as shown in **Figure 2.3**. This corresponds to less than 1% of the worldwide production. **Table 2.1** indicates the amount of bauxite produced yearly by the country between 2003 and 2009.

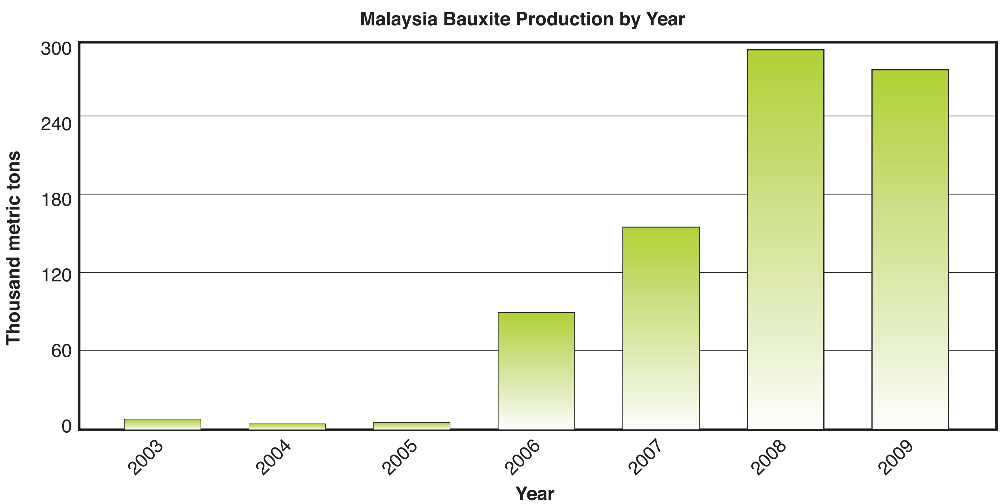


Figure 2.3 Malaysia yearly bauxite production

Source: United States Geological Survey (USGS) Minerals Resources Programme

Table 2.1 Malaysia Yearly Bauxite Production

Year	Production	Unit of Measure	% Change
2003	5.69999980926514	Thousand metric tons	NA
2004	2.03999996185303	Thousand metric tons	-64.21%
2005	4.7350001335144	Thousand metric tons	132.11%
2006	91.8059997558594	Thousand metric tons	1,838.88%
2007	156.785003662109	Thousand metric tons	70.78%
2008	295.175994873047 S Sy	Thousand metric tons	88.27%
2009	280	Thousand metric tons	5.14%

Malaysia's bauxite resources are located at Bukit Batu, Bukit Gebong, Lundu-semantan and Tanjung Seberang in the State of Sarawak and at Bukit Mengkabau and Labuk valley in the State of Sabah. The two operating bauxite mines in Malaysia are located at Sungai Rengit in the State of Johor.

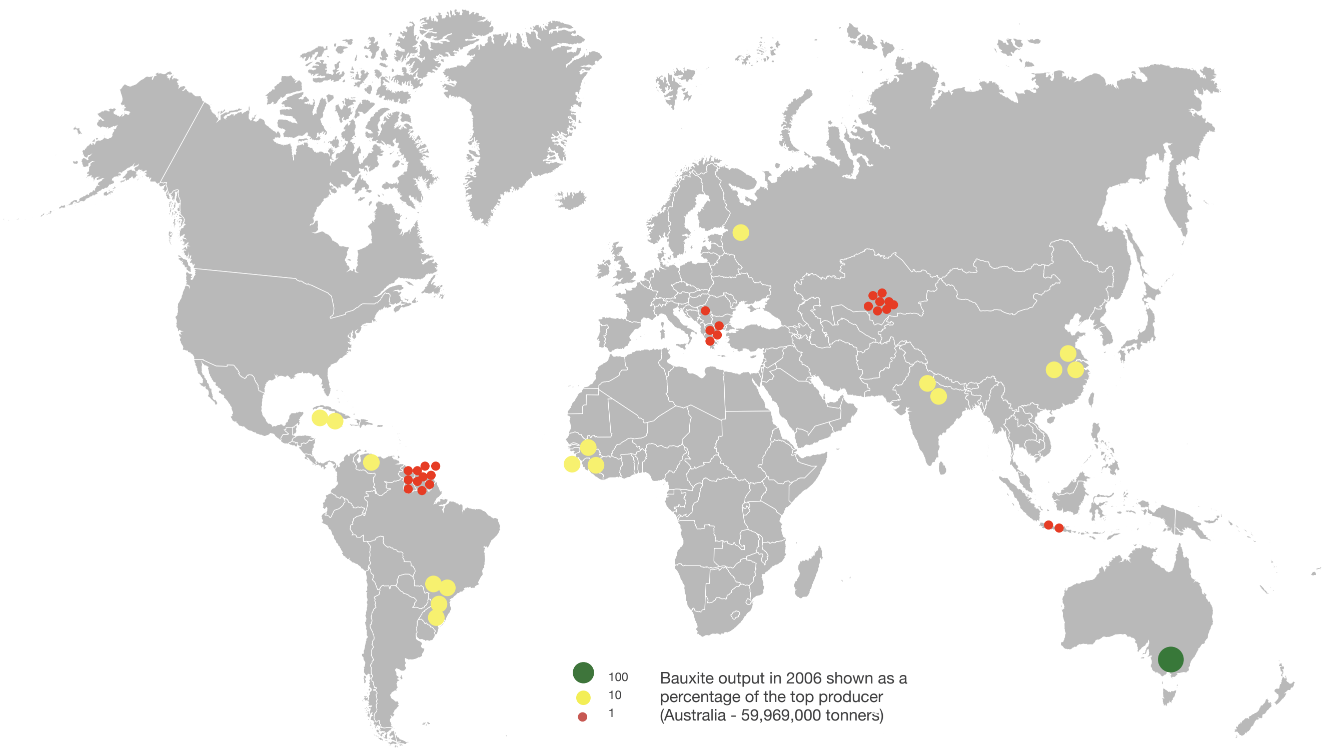


Figure 2.4 Worldwide bauxite output

2.2.1.2 RECOMMENDATIONS

Even though the amount of bauxite resources in Malaysia is small compared to worldwide production, this may be the starting point for Malaysia to venture into front-end sapphire substrate manufacturing. Once the focus has been set, further exploration can be made to find the raw materials. In addition, the raw material can be imported from neighbouring countries such as Indonesia, which has 16,000,000 tonnes of bauxite if the demand is high. **Figure 3.4** shows world bauxite output in 2004.

One of the key advantages of moving-up value chain in substrate manufacturing and setting up local players for substrate production with local raw materials is the assumption that the price for the wafer can be further reduced. This will not only help Malaysia gain significant market share, but will also contribute to bringing down the price of the compound semiconductor-based devices.

Figure 2.5 shows the forecast for sapphire wafer price until 2020. To remain competitive and successful in the challenging industry, it is important to be part of the value chain, working towards better quality substrate material through R&D and at the same time able to produce cheaper wafer for example, a 6 inch sapphire wafer that cost less than USD4. The market opportunity for substrate industries such as sapphire or other compound semiconductor wafers is at the large wafer level. Based on data extrapolation, the market opportunity for 6-inch sapphire wafer will continue to grow until 2020. **Figure 3.6** shows the market opportunity for sapphire wafer.

Other than sapphire, as a substrate manufacturer there are several materials that can be investigated to be produced locally. Some of the materials that currently being used as the wafer for compound semiconductor devices are Gallium Nitride, Silicon Carbide and Silicon. The following is a list of advantages and disadvantages of wafer materials (Widney, Douggreentechmedia 2012):

Sapphire: Users include almost all players except Cree Lattice mismatch: 13%;

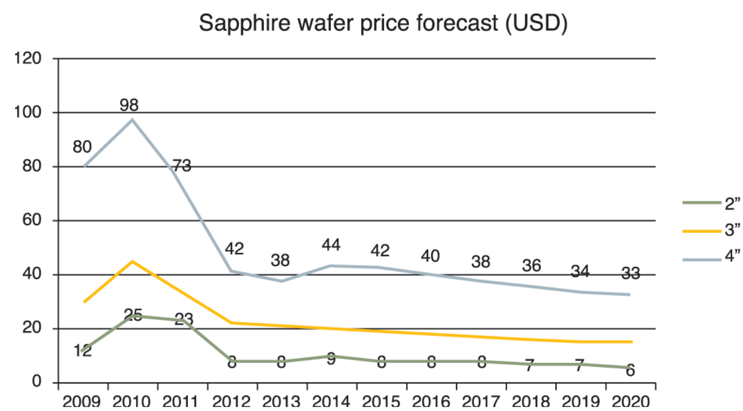


Figure 2.5 Sapphire wafer price forecast

Source: Canaccord estimate model

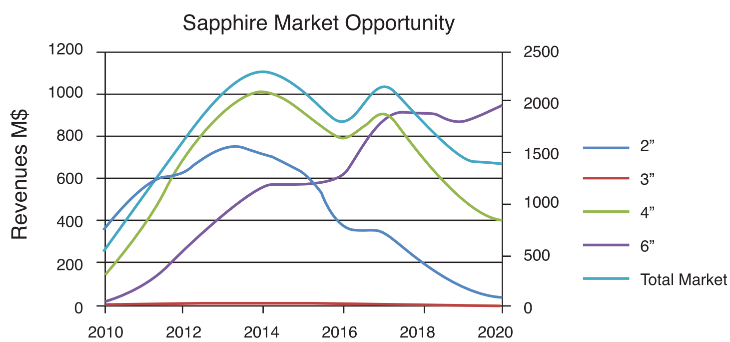


Figure 2.6 Market opportunities for Sapphire wafer

Source: Canaccord estimate model

Advantages: Stable, mismatch well researched;

Disadvantages: Quite expensive.

Silicon Carbide: Users: Cree; Lattice mismatch: 3.5%;

Advantages: Very stable. Low mismatch aided by cancelling thermal mismatch, highest thermal conductivity;

Disadvantages: Priciest, almost proprietary;

Silicon: Research maturing in OsramOpto, Bridgelux, China; Lattice mismatch: 17% (plus a 56% additive thermal mismatch);

Advantages: 80% substrate cost reduction potential, ubiquitous, big wafers;

Disadvantages: Lattice and thermal expansion huge mismatches;

Gallium Nitride: Users: Soraa; Lattice mismatch: 0%;

Advantages: Very good Lattice and thermal match, homogeneous material allows higher drive level by tuning the GaN for reduced droop; and

Disadvantages: Unstable, defect-ridden and quite expensive.

Another opportunity is venturing into totally different materials, which requires huge effort in terms of research and development and a long time before gaining any market share. This is suitable for long term target. Some of the materials that can be researched include glass, germanium, and Aluminium Nitride (AlN).

2.2.2 LIGHT EMITTING DIODE (LED)

The Light Emitting Diode (LED) value chain consists of several steps to manufacture LED devices on top of the wafer/substrate. The value chain can be divided into two section based on the value-added: front-end or high value-added and back-end or low-value added.

2.2.2.1 OPPORTUNITIES

The front-end part starts from a substrate/wafer. The substrate may come from a different industry (e.g. substrate manufacturing industry). The next step will be the semiconductor material epitaxial process on the wafer. The type of semiconductor material depends on the colour of the LED. Different materials with different energy band-gap will produce different colour. To illustrate, Gallium Nitride (GaN) is used for blue LED. Once the epi-wafer has been completed, the device fabrication process begins. This includes lithography, etching, metallisation and several other fabrication processes. At the end of the process, the LED dyes will be created on the wafer. This marks the end of the front-end part.

The back-end activity starts from the dyes on the wafer. The wafer with fabricated LED will be diced into individual LED dyes. This individual LED dye will be binned based on the quality and packaged with other circuitry and housing. For a white LED, a phosphor coating will be applied so that the white colour can be produced when the blue light hits the phosphor. The packaged LED can be assembled into different types of LED lamps of lights creating solid-state lighting. **Figure 2.7** illustrates the complete value chain for blue LED manufacturing. The basic steps will be the same for different colour LEDs, except for the semiconductor materials and some extra processes like phosphor coating.

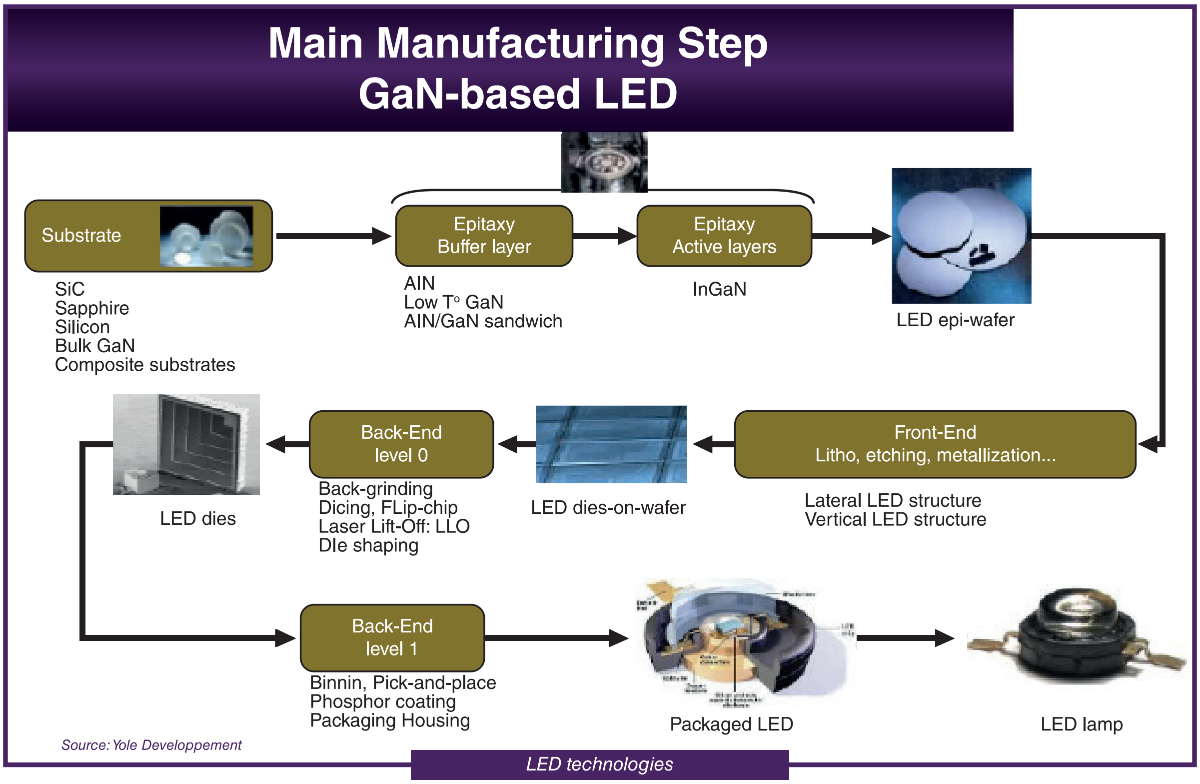


Figure 2.7 LED device manufacturing value chain

The production of LED lamps and luminaires can be termed LED lighting or solid-State lighting (SSL). If LED lighting is included with LED chip fabrication, the total value chain including all the elements in LED technology can be divided into 5 different segments as follows: materials, LED chip and lighting components, final product, distribution, and sales as shown in **Figure 2.8**.

The manufacture of solid state lighting comprises product design, product manufacturing, marketing and selling. This is the lower-value added part of the value chain and many Asian countries take part in these activities, including Malaysia. This includes local companies as well as global companies that outsource their manufacturing to Asian subcontractors such as Cree, Philips Lumileds and OSRAM. OSRAM and Philips Lumileds maintain packaging and manufacturing plants in Malaysia. **Figure 2.8** reveals certain major players in the LED industry, along the value chain. It can be seen from the Figure that companies such as Osram and Philips Lumileds play major role in the upstream and downstream of the value chain while some companies like Cree and Nichia only focus on the higher value added stage.

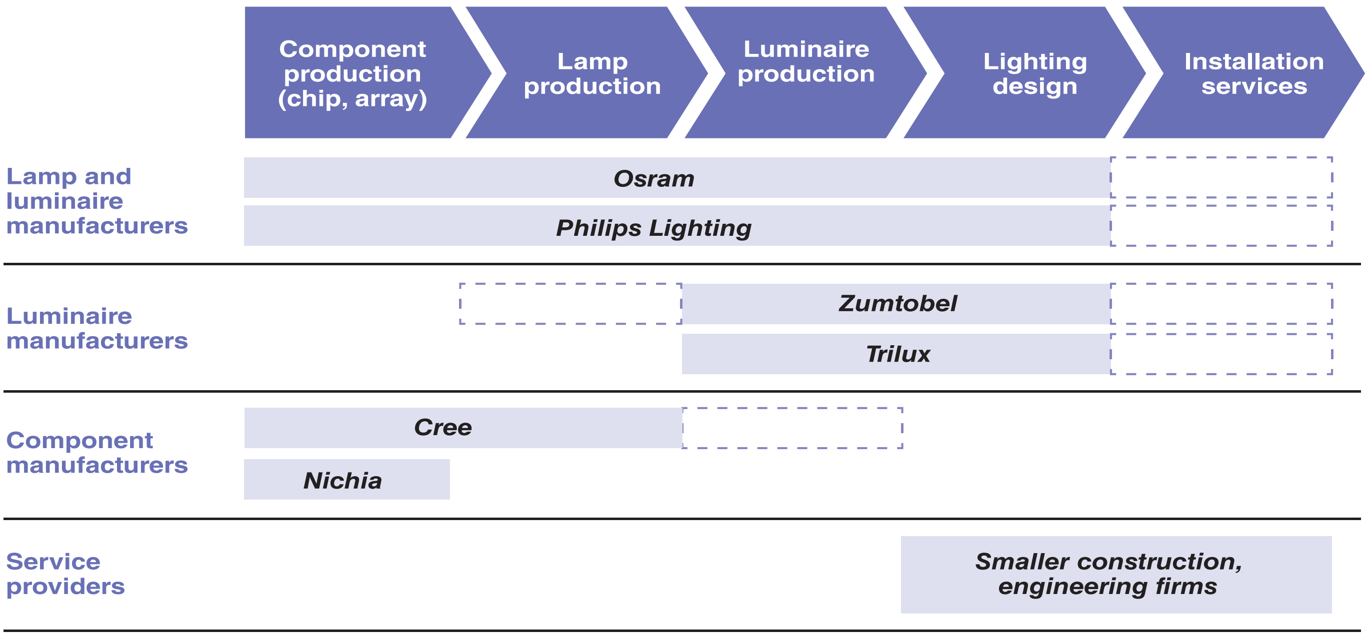


Figure 2.8 Certain big players along the LED value chain

Source: A.T. Kearney Analysis

2.2.2.2 RECOMMENDATION

Generally, Malaysia already participates in the back-end or lower-added in the value chain. Malaysia currently exports RM1.8 billion (2008 data) of LED which represents approximately 10% of the global LED market, with most of these exports in the illumination (luminaire) sector. Thus, Solid State lighting is one of the fastest growing sub-segments, projected to grow at 28% per annum over the next 10 years to a size of RM170 billion (Source: Economic Transformation Programme – A Roadmap for Malaysia).

Currently, four of the largest global SSL companies either operate in or control a significant portion of work to companies in Malaysia. There are also a number of companies involved in other areas of SSL such as contract manufacturing, systems integration, LED packaging, and application design as well as speciality companies focused on various heating and optical elements.

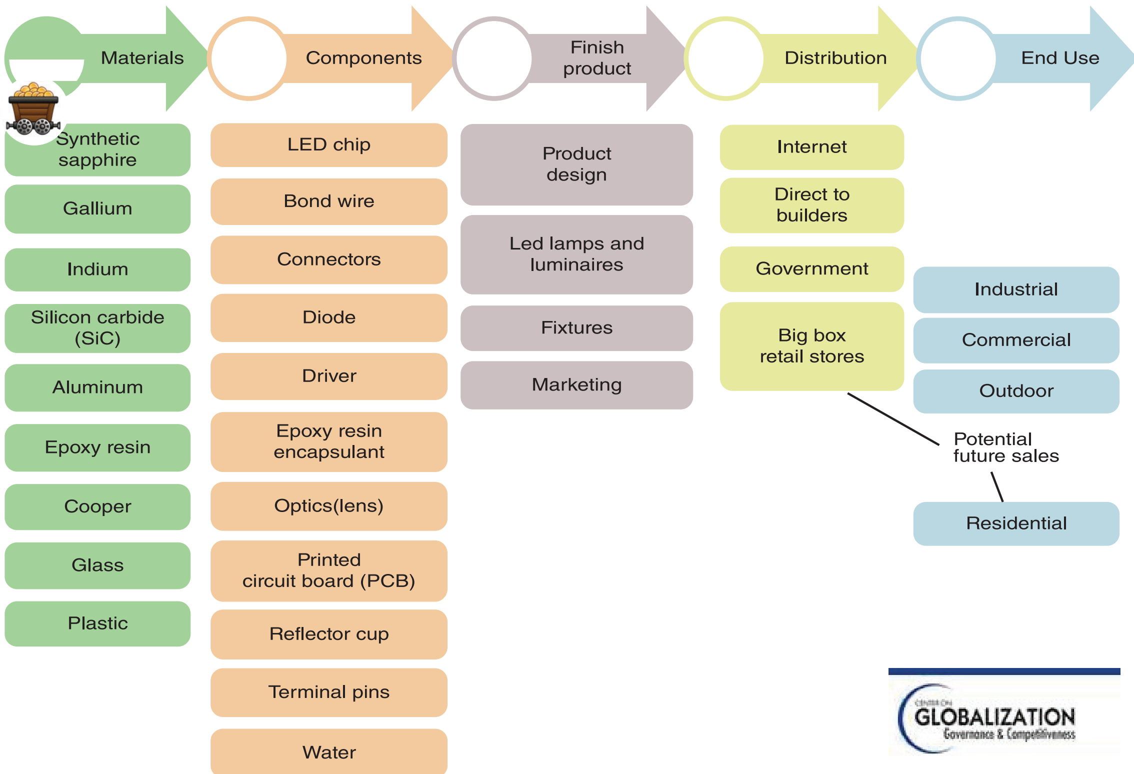


Figure 2.9 LED lighting industry value chain

Source: Centre on Globalisation, Governance and Competitiveness, CGGC report

Since Malaysia has already established itself in the lower-added value of the value chain, it is the time for the country to move-up to the higher-value added sectors and the local companies should play major role in this activity. Climbing the higher-value-added value chain means Malaysia must venture into LED device fabrication. This involves epitaxial on-wafer processes and device fabrication. In other words, Malaysia requires a compound semiconductor fabrication facility or foundry. This foundry can serve the fabrication of monolithic microwave integrated circuit (MMIC) as well. In this regard, at least two companies can be created one for the epitaxial process and another one for the device fabrication.

2.2.3 MONOLITHIC MICROWAVE INTEGRATED CIRCUITS (MMICS)

The value chain of MMIC manufacturing more or less similar with silicon-based CMOS IC manufacturing where there are two different value chains, one for the circuit design process where the whole design process starts with specification, until layout will be done by a design house and the second value chain involves the fabrication process of the MMIC. In general, once a MMIC circuit has been designed, the design will be sent to a foundry for the fabrication. The dissimilarity from CMOS fabrication lies at the fabrication process steps, as in MMIC fabrication, compound semiconductor materials will be used and therefore, the process involves epitaxial growth of the compound semiconductor on the substrate. **Figure 2.10** shows the simplified value chain for MMIC fabrication.

2.2.3.1 OPPORTUNITIES

Similar to LED device manufacturing, the process starts with an appropriate substrate or wafer. As explained earlier in this chapter, substrate or wafer alone is an industry by itself and has its own value chain. Therefore substrate manufacturing and MMIC fabrication or LED device fabrication, all of them inter-related and complement each other (i.e. substrate manufacturing industry requiring the MMIC or LED fabrication industry and vice versa).

Once the substrate is ready, the next process is epitaxial growth of the compound semiconductor material on the wafer. Next, is the device fabrication on the epi-wafer that it use to complete the integrated circuit. (The individual dies on the wafer will be sliced and packaged, then be integrated on the MMIC system).

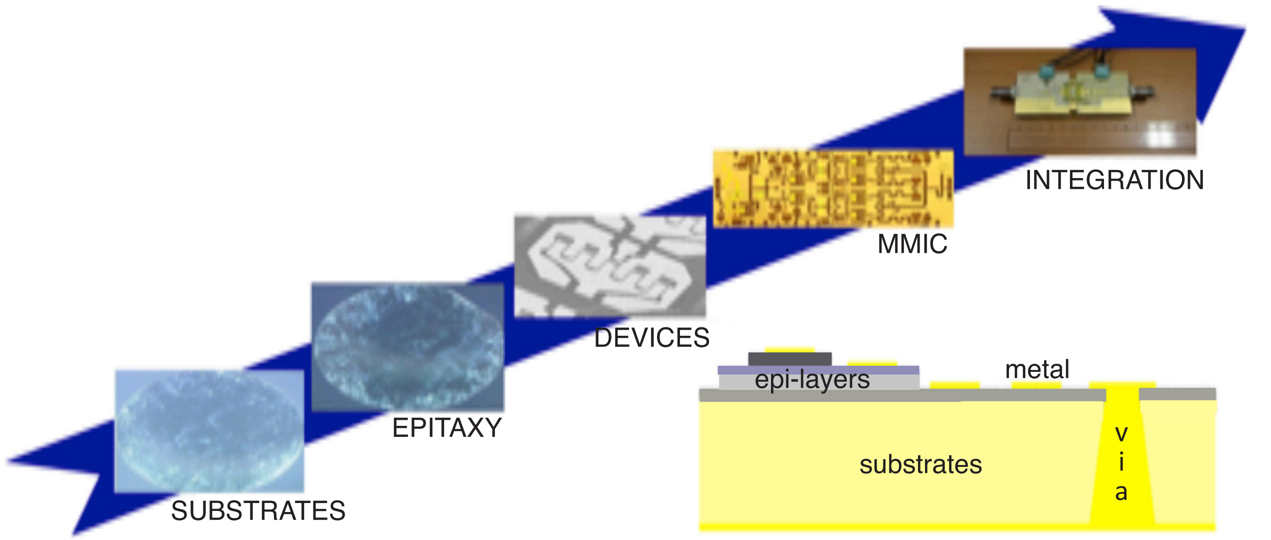


Figure 2.10 MMIC fabrication value chain

2.2.3.2 RECOMMENDATION

Most integrated circuit designs and fabrication activities in Malaysia focus only on the CMOS design process, which involves semiconductors other than compound material. The worldwide semiconductor market (not specific to compound semiconductor) is currently valued at RM812 billion (2009) and is expected to grow at about 7% per year. The output value of semiconductors in Malaysia is around RM39 billion (2009), a global share of 5%. However, the majority of the semiconductor market in Malaysia is predominantly focused on silicon-based products and the semiconductor firms operating in Malaysia concentrate primarily on assembly and testing. However, there are few a few CMOS IC design house in Malaysia and one locally owned CMOS IC foundry (Silterra).

Currently, there is no commercially viable local company for MMIC design and no local player for MMIC fabrication. Nevertheless, there are several research and development centres located at the universities and government-linked companies conducting research on MMICs. However, due to the lacking of compound semiconductor foundry, the research cannot be translated into actual products.

Malaysia should take this opportunity to participate in MMIC value chain from front-end all the way to the back-end. Local IC design house can created and one local compound semiconductor foundry can be developed to create the complete ecosystem. Together with substrate manufacturing industry and compound semiconductor foundry, the whole value chain can be covered, not only for the MMIC industry but also the LED device industry.

2.3 CONCLUSION

The compound semiconductor industry, through light emitting diode (LED) applications and monolithic microwave integrated circuit (MMIC), is a billion dollars industry and will continue to grow rapidly. Industries all over the world are working very towards the improvement of the technology, as mention in finding better materials and techniques to be the market leader and control significant portion of the market share.

While the number of companies and countries participate in this industry is huge and reach various continents but significant market share is controlled by few companies from the US and Europe. These few companies participate in the front-end part of the value chain. The back-end part is taken by many companies from Asian countries.

Malaysia has taken part in this industry and is now actively participating in the back-end of the value chain. In order to become a big player in the industry, Malaysia must move up the value chain and become involved in the higher-value segments. This requires huge effort and investment, be it ineithermonetary, human capital, infrastructure or governmental policy terms. This chapter has explored the complete value chain related to compound semiconductor industry in particular for three different sectors: substrate manufacturing, LED manufacturing and MMIC manufacturing. As such as detailed understanding of the value chain is required before necessary action plan can be proposed for the transformation of the country toward higher-value added sectors.

CHAPTER 3
COMPOUND SEMICONDUCTOR: PLAN OF ACTIONS AND ROADMAP

The electronics and electrical sector is an important contributor to the national economy, accounting for RM37 billion GNI ,which represent 6% of the nation GNI, 522,000 jobs and 41% or Malaysia total exports in 2009 (Economic Transformation Programme report).

Nevertheless, E&E sector in the country faces significant challenges to maintain the growth especially from the competition from China, Taiwan, Singapore and many Asian countries. Under the national transformation programme, E&E sector has been chosen as one of the sectors that can move the country forward and achieve the vision 2020. The public, private sectors, and the whole nation should face the challenges and take part in the national agenda to achieve the vision and move forward beyond it.

3.1 SCOPE AND STRUCTURE OF THE ROADMAP

The Science, Technology, and Innovation (STI) sector will be a strategic key player and the Mega Science Agenda will be the bedrock and platform for the journey. For this purpose, E&E has been chosen as one of the sectors for the Mega Science Framework, and the compound semiconductor industry has been identified as one of the subsectors that have potential for STI sustainable development and growth.

To achieve this ambitious goal, sector members have undertaken an effort to develop a series of roadmaps and action plans covering different segments of the sector including research and development (technological roadmap), institutional framework and policies and infrastructure development. This roadmap provides a foundation for identifying a set of effective technologies, economies, policies, institutions, and milestones that will allow compound semiconductor industry in Malaysia to grow and give a significant contribution to the national economy, technological advancement and human capital development, as well as being part and parcel of becoming a developed nation.

3.2 ROADMAP METHODOLOGY

This roadmap was developed and compiled using inputs from wide range of stakeholder information obtained through several methods, including internet search, workshops, surveys and interviews from the LED industry, IC industry, wafer/substrate supplier, academic institutions and government agencies. This roadmap should be regarded as a work in progress and as the technology, market, and regulatory environments continue to evolve, some information and analyses will need to be updated and additional tasks added.

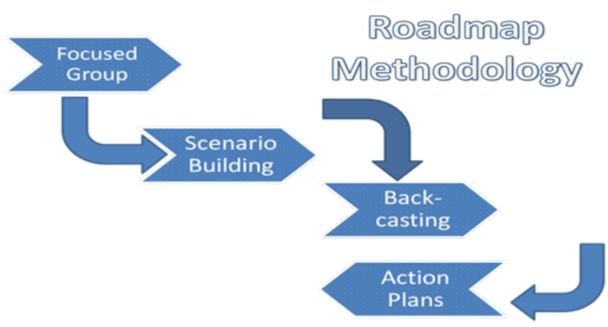


Figure 3.1 Roadmap Methodology

The roadmap methodology consists of four different steps, as depicted in **Figure 3.1**. The development starts with defining focus areas. This means to select several areas under the research theme that will be the core sectors. For compound semiconductor sector, the focus areas are substrate manufacturing, LEDs, and MMIC. The next step is scenario building. Basically this is the process of predicting the future before it happen. The scenario must be something futuristic yet plausible. Once the scenario or scenarios have been defined, the next step will be backcasting.

This step is different from the conventional roadmap methodology that uses forecasting method. In backcasting the necessary paths are developed starting from the future (based on scenario) and bringing back to present time. This is to avoid constraining the mind with current limitations hence promoting outside the box kind of thinking. Once the development paths have been completed through backcasting, necessary action plans can be prepared to fulfil all the milestones along the path.

Chapter 1 and 2 of this report describes the base line, including the technology and the value chain of three different industries related to compound semiconductors: substrate manufacturing, LEDs and MMIC. The proposed roadmap will cover all these industries as a whole, and emphasis will be given for Malaysia to participate in the total value chain including upstream and downstream. Hence, there will be three different stages of the roadmap; starting with the short term plan (2013-2020), medium term plan (2020-2030) and long term plan (2030-2050).

3.2.1 SCENARIO BU

The future scenario that will be predicted is at the year 2050 and beyond which is the long term stage. The scenario for Malaysia, by the year 2050, is that it will be a market leader for consumer electronic products with significant market shares. This scenario is made due to the correlation between developed countries with electronic industry.

To illustrate, Japan is a developed country and its electronic industries are one of the main driving factors to this. Companies like SONY started just after the Second World War, when Japan lost a war. And, now, they are one of the main contributors that have shaped Japan to what it is today. Samsung is another electronic industry that has helped Korea to be one of the high income countries. Both of these companies have strong support from their governments as they are seen as valuable national assets. Hence, this is what Malaysia should do to establish our own electronic industry as soon as possible.

One of the challenges that will be faced by Malaysian electronic industry is strong competition from global established industries. There are several ways to tackle this problem. For a start, Malaysian electronic companies should target to capture the local market instead of going global. This can be done if the product is high quality and State of the art technology as well as priced reasonably.

Pricing and performance are key factors and there is a possibility to achieve the target if the complete value chain can be done locally. For instance, smartphone has been chosen as the first product to establish Malaysian electronic companies. In order for Malaysian smartphone to attract significant market share locally, the phone should be competitively priced with State of the art technology or at least on par with other brands. To be part of the global market and gain significant market share, a scenario in which Malaysia is a global player and market leader can be predicted. This scenario can be made a possibility with the following targets:

i. New display technology that includes a translucent and flexible display.

ii. New MMIC technology with low cost, low power, and ultra-wide bandwidth system on chip.

iii. New substrate technology that offers very high quality and low cost for LED and MMIC fabrication or

iv. LED display technology that uses other materials for LED device fabrication such as plastic or glass.

As can be seen from this scenario and the events behind it, that scenario covers all focus areas in the compound semiconductor industry (e.g. substrate manufacturing, LEDs and MMIC)

In this scenario, low price and high performance smartphone is chosen as the business entity and the market share as the key performance index (KPI) for the scenario due to its role in driving the compound industry market. Nevertheless, smartphones are not the only business entity that Malaysia will take part in. Some other consumer electronic products may be included. The proposition is that a Malaysian electronic company may become the next Sony, Samsung, or Apple.

Furthermore, this scenario will also complete the eco-system for the product cycle. The companies that produce the next generation smartphone and other electronic products will serve as the market for all other industries. In other words, this creates a market for all other businesses such as wafer/substrate manufacturer, Fabrication Company, packaging company, IC design house, and sales and distribution. **Figure 3.2** shows this scenario that will set the targets for Malaysia to become a key player in the compound semiconductor industry.

Looking at the scenario, one of the key aspects is cost. As seen from the above list, low cost is one of the factors of the scenario. Therefore, covering as much as possible the whole value chain from front-end to back-end will be crucial in achieving this target. Advance technology through R&D activity will also be part of the low-cost activity. In addition, new institutional frameworks, policy and infrastructure need to be developed to achieve the final vision.

Another area that can be considered in order to establish the Malaysia electronic industry is to begin with products or solutions that solve local issues and problems. This approach is similar to how technology is developed by the Americans, as they start with solutions/products that are required by their military. The military requirement opens up opportunities for local companies to come up with ideas and solutions, which at the end lead to new breakthroughs and overtime these breakthroughs reach consumer electronics.

Similarly, the Malaysian Government can initiate grand challenges ideas/projects crucial to Malaysia. For example, say that the local broadcasting media are attempting all-digital broadcasts and that for these purposes Malaysians need digital set-top boxes in every house. This can be a grand challenge to local

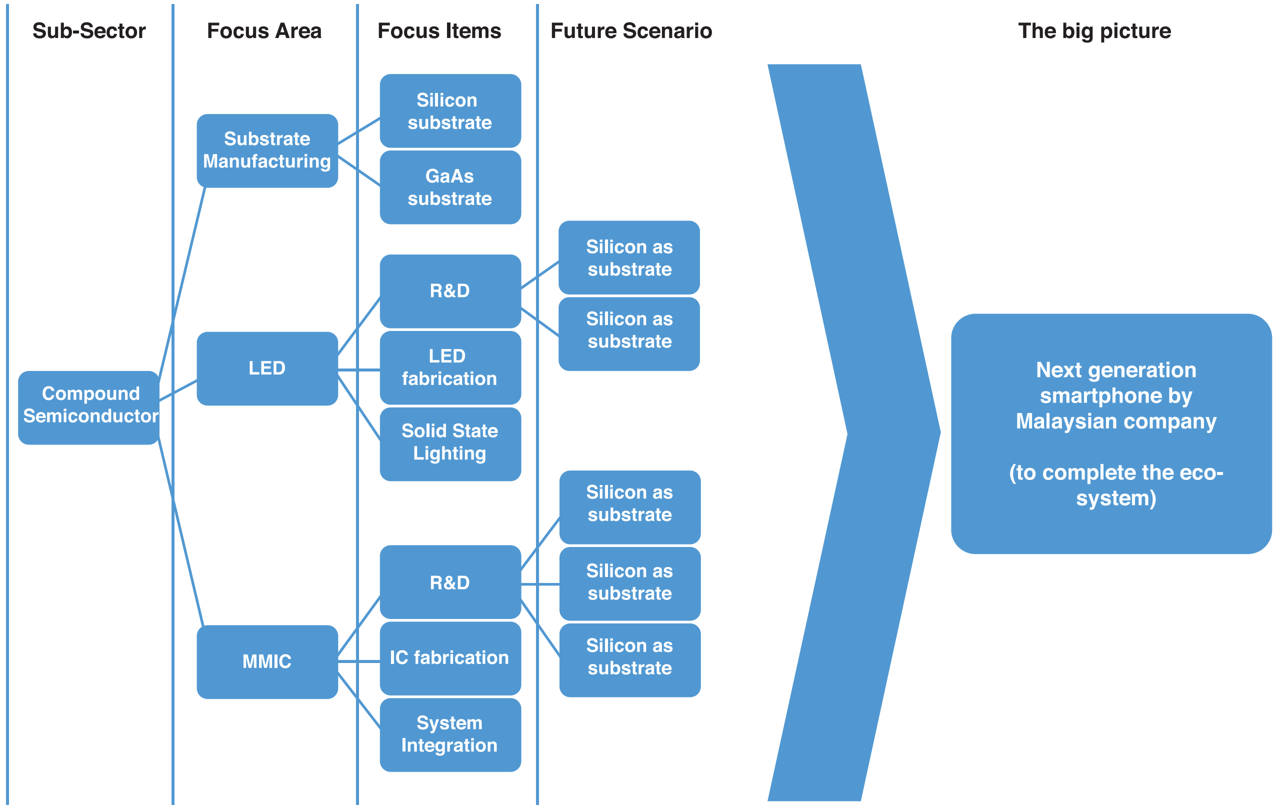


Figure 3.2 The Scenario

companies/individuals/groups to propose a digital set-top box that is Malaysian made or has at least 70% local contents. This may be the first product to establish Malaysian electronic companies.

Due to the demands for this product, the market size is substantial and every value chain along the production will benefit from the ready market. This product may also be a catalyst to spearhead bigger business opportunities in other segment of the electronic industries. There are many other challenges that can be thought of which solve Malaysian problems. The government can play a bigger role to initiate the challenges.

3.2.2 ROADMAP STAGES

There are three different stages for the roadmap: first term (2013-2020), medium term (2020-2030), and long term (2030-2050). Therefore, there will be three different features to cover all the stage and each feature will have several events to describe the feature. The following are the features and events for the three different terms:

Establishing the foundation for the compound semiconductor industry

In the near term or for the short term, compound semiconductor industry in Malaysia will be established.

This will includes all the necessary events to start and grow the local industry to be the player at higher value-added part in the value chain. For instance, an epitaxial process industry will be developed locally for the LED device fabrication. This will mark a shift of the value chain in LED manufacturing from packaging to the epitaxial process to creating the epi-wafer. **Figure 3.3** shows events for the first term feature.

Expansion of technology

Once the foundation for compound semiconductor has been established in the short term, Malaysia will be ready to expand the industry to include new state-of-the-art technology in every segments of the industry with the emphasis to improve the product and bringing down the cost. This includes wafer manufacturing, LED

Figure 3.3 Establishing Malaysia's compound semiconductor industry

manufacturing (Epitaxial growth, device fabrication and LED packaging), and OLED manufacturing. **Figure 3.4** illustrates the medium-term events.

Next generation technology

The final term (long-term plan) marks the beginning of future generation technology. In turn, certain technologies which also have been introduced in the medium term as well as the final term. These technologies will be sufficiently established to drive the future of compound semiconductor industry in Malaysia. Meanwhile, several new fundamental technologies will be introduced at the beginning of the long-term plan and targeted to be completed and transform into mass production by the end of the term. For instance, phosphorescent organic LED (PhoLED) will be introduced and developed, bringing a brighter future for the LED business. **Figure 3.5** shows events for the long-term plan.

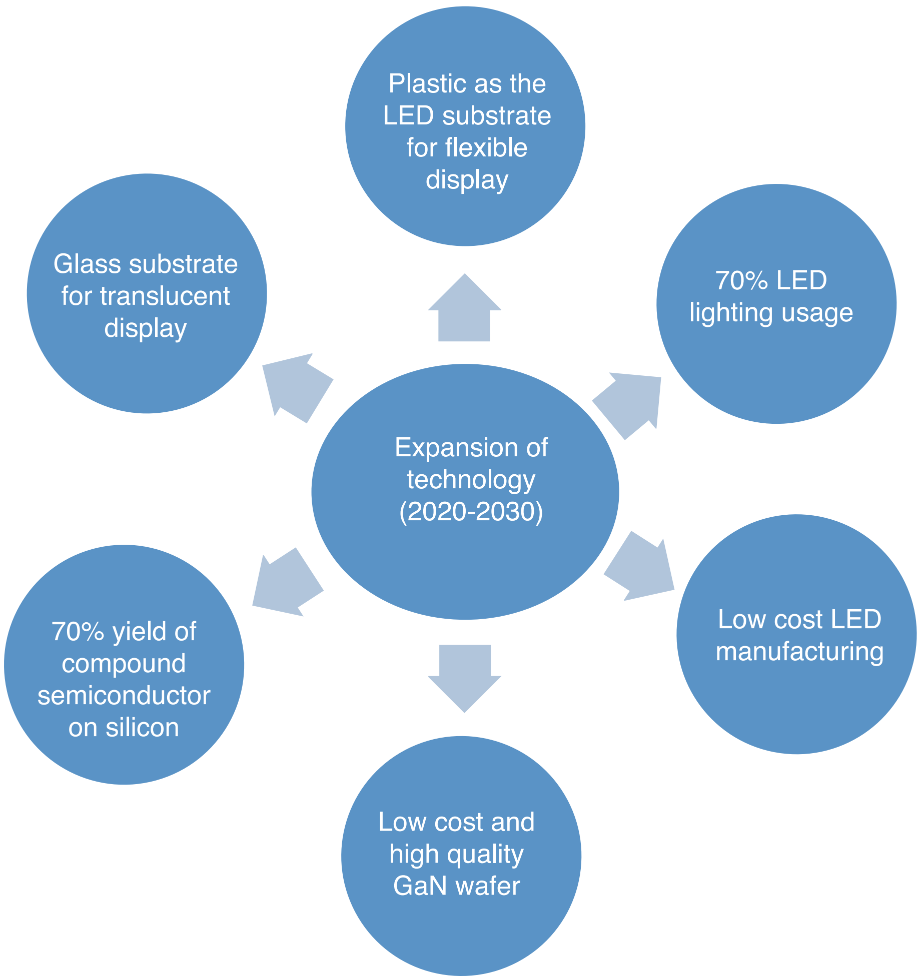


Figure 3.4 Expansion of new technology for compound semiconductor

3.3 GOALS, MILESTONES AND ACTION PLAN

The features and events proposed in the previous section are part of the backcasting process. Since the target in 2050 is for Malaysia to be global leader in smartphone business through low price and State-of-the-art technology, this scenario has been back-casted to three different terms in order to realise the vision.

The backcasting flow is carefully planned so that to be the market leader in 2050, the final term plan should shape the industry towards next generation technology. To achieve the final term plan, the medium-term should establish the expansion of new technology and finally in order for the medium-term to expand the technology, the necessary foundation must be established in the first term.

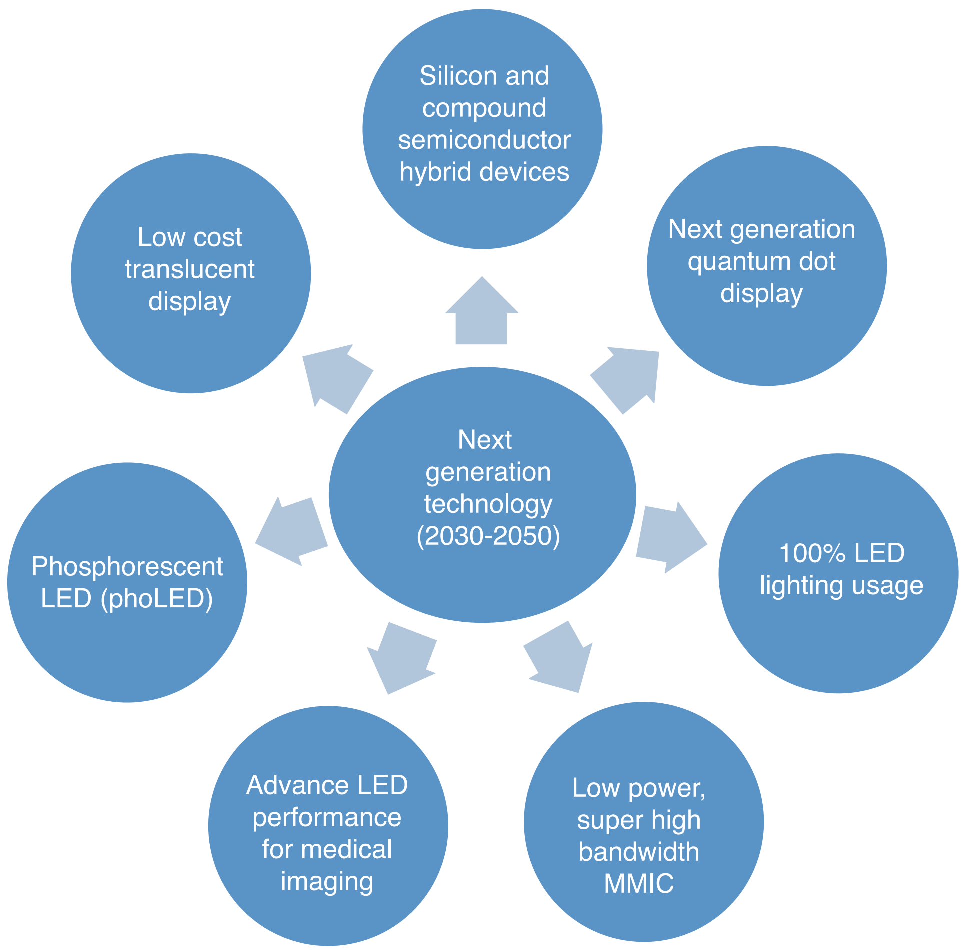


Figure 3.5 Next generation compound semiconductor industry

From all the proposed features and events throughout the terms, the final step in building the roadmap is to create action plans and milestones to achieve these goals. This section will present the necessary action plans for three different terms. For all terms, emphasis will be given to achieving low-cost targets while pursuing advancement in the technology.

3.3.1 SHORT-TERM ACTION PLAN (2013-2020)

The goal for the short term is to establish the compound semiconductor industry in Malaysia. The main ingredient in achieving this first term is for Malaysia, especially local companies, to venture into all other value chain in the industry. In substrate manufacturing industry, Malaysia should have its own crystal growth process not only for compound semiconductor substrate but also for silicon substrate. This involves the process of converting raw materials into crystal ingots and finally a sliced wafer. **Figure 3.6** shows an overview of the LED manufacturing industry that covers the total value chain. In order for Malaysia to establish this industry, participation from every segment except manufacturing equipment is required.

Emphasis will be given to activities to reduce the cost of the product. The cost reduction of the final product involves an understanding of the source of costs at each key stage in the manufacturing process, and requires careful attention to the design of the product and of the manufacturing process.

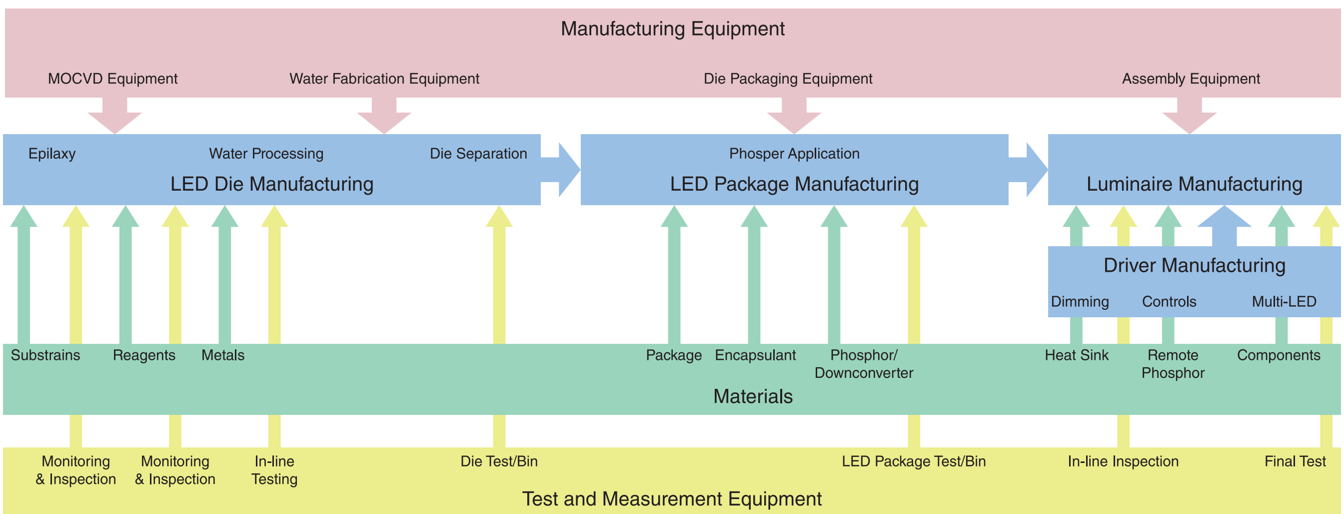


Figure 3.6 LED manufacturing industry

Source: USA Department of Energy, SSL R&D-manufacturing roadmap

The typical cost breakdown for an LED package is shown in **Figure 3.7**. The data represents high vol. manufacturing of 1 mm^2 dye on 100 mm diameter sapphire substrates and packaging of the dye to produce high power warm white phosphor-converted LED lighting sources. The Figure indicates that that a significant proportion of the cost contributes by the dye-level packaging stage. Nevertheless, this result is not surprising as the final product is a packaged dye, and there are many thousands of such dyes on each wafer (around 5,000 1 mm2 dye on a 100 mm diameter substrate).

Therefore, costs associated with dye-level activities will tend to dominate and manufacturers will need to address dye-level packaging processes or perform more of the packaging activities at a wafer level in order to realise the required cost reductions. **Figure 3.8** demonstrates how the LED package cost elements predicted to change over time, falling to about 17% of 2013 values by 2020.

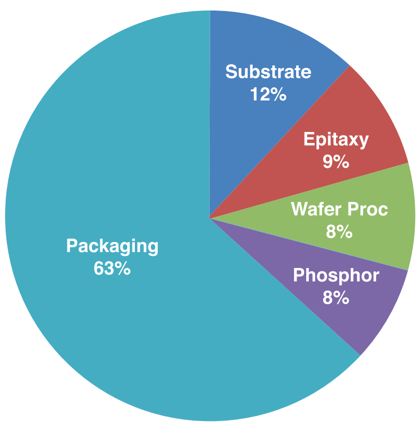


Figure 3.7 Cost breakdown for an LED manufacturing

Source: USA Department of Energy, SSL R&D-manufacturing roadmap

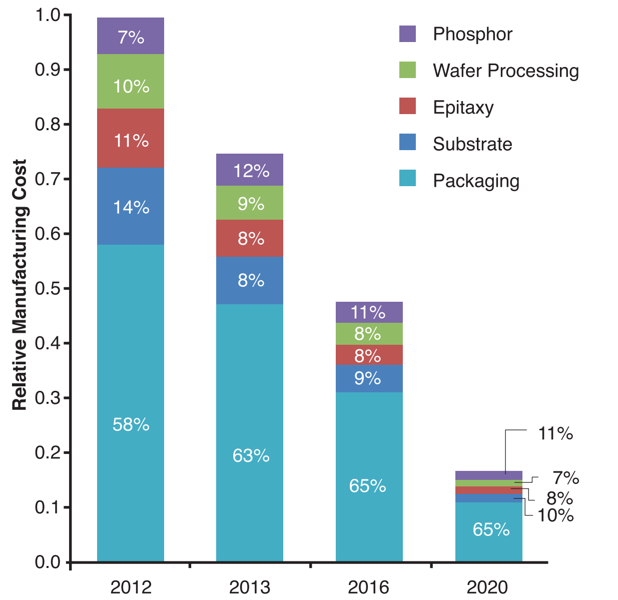


Figure 3.8 Cost reduction projection of LED manufacturing

Source: USA Department of Energy, SSL R&D-manufacturing roadmap

3.3.1.1 RESEARCH AND DEVELOPMENT

In the short term, Malaysia will establish a local compound industry through substrate manufacturing, LED dye manufacturing (epitaxial growth, LED device fabrication, LED packaging), luminaire manufacturing, and MMIC design and fabrication. **Table 3.1** shows all the activities for the first term plan, with regards to R&D progress.

Table 3.1 First term roadmap action plan for R&D

Goals	Action Plans	Target
Substrate manufacturing	• Establishing and improving substrate for heteroepitaxial growth (sapphire and silicon) • Establishing and improving substrate for homoepitaxial growth (GaN for GaN-on-GaN LED) • Establishing Silicon substrate manufacturing	1. Production of sapphire and GaN substrate 2. Bigger substrate (>150mm for sapphire and 200mm for silicon)
Epitaxial growth	• Establishing and improving epitaxial growth process for heterojunction ○ Wafer uniformity (standard deviation of wavelength for each wafer) ○ Wafer-to-wafer reproducibility (maximum spread of mean wavelength) ○ Cost of ownership (COO)	0.50nm 0.50nm 50% reduction
Device fabrication (LED and MMIC)	• Establishing and improving device fabrication process ○ Introduce new compound semiconductor process technology ○ Innovation to reduce cost and improve performances ○ Deposition of phosphor layer prior to wafer dicing	New GaAs and GaN process technology i. Introduce larger diameter wafers ii. Introduce multiple dye architecture Process reduction at chip level (30% reduction)

3.3.1.2 INSTITUTIONAL FRAMEWORK AND POLICIES

Development in the compound semiconductor value chain will not be complete without institutions to support the industry especially for R&D activities. On top of that, some policies must be devised and existing policies may need to be modified in order to enable a smooth transformation in growing the industry. **Table 3.2** presents the goals, action plans, and targets in the first term for institutional framework and policies.

Table 3.2 First term roadmap action plans for institutional framework and policies

Goals	Action Plans	Target
Research and Development centre	• To create R&D centre at national university for the following fields:- o Substrate manufacturing technology o Compound semiconductor fabrication (LED, MMIC) o New material science	At least one R&D centre for every field.
Skill development centre	• To develop curriculum and training for skill development centre for human capital	Modules for compound semiconductor industry
LED adoption as lighting standard	• Governmental policy to insist on utilising LED as the chosen lighting for street and government offices	40% LED utilisation
mega challenge projects to solve local issues and problems	• Government to initiate mega challenge to be taken by local companies/groups to solve country issues/problems. Examples: o Dengue virus rapid detection device o Digital set-top box in preparation for all-digital broadcast o Automatic/robotic system to be used in the palm sector	At least one mega challenge initiated by the government as a start-up project. 70% local content requirement for all proposed solutions/products

3.3.1.3INFRASTRUCTURE DEVELOPMENT

Moving up the value chain in compound semiconductor industry involves huge capital investment in infrastructure. The front-end part of the industry requires several state-of-the-art facilities including substrate manufacturing plant, device fabrication facility and R&D facility. All these facilities are crucial for participation in front-end activities. **Table 3.3** presents the infrastructure development needs of the industry.

Table 3.3 First term roadmap action plan for infrastructure development

Goals	Action plans	Target
Substrate manufacturing facility	• To develop substrate manufacturing facility for: ○ Sapphire substrate ○ Silicon substrate ○ Gallium Nitride substrate	At least one substrate manufacturing facility completed in 2016
Epitaxial growth facility	• To create epitaxial growing facility for heteroepitaxial (Sapphire and Silicon) and homoepitaxial (GaN) • To convert existing CMOS foundry/clean room to include LED fabrication capability. One of the MIMOS facilities can be modified to add LED manufacturing.	One epitaxial facility by the year 2016 MIMOS as one of the LED fabrication facilities in Malaysia
Compound semiconductor foundry	• To create compound semiconductor fabrication facility that capable to fabricate LED and MMIC.	One compound semiconductor foundry by 2016
Improving existing LED packaging and luminaire manufacturing plant	• Introducing new innovation for existing facility targeting at cost reduction of LED manufacturing	30% cost reduction in LED packaging and luminaire manufacturing
GLC for sales and distribution company as the market for compound semiconductor industry	• Setting up a company for sales and distribution to complete the eco-system of the compound industry (target product: smartphone)	GLC based local brand company for smartphone business

3.3.2 MEDIUM-TERM ACTION PLAN (2020-2030)

The medium term action plan is to further develop and expand the compound semiconductor industry in the country to embrace new technology. Application of new innovative technology is important, especially in producing low cost products. This is to ensure the sustainability and relevancy of the industry and to maintain its competitiveness. **Table 3.4** shows some of the action plans for the medium term.

Table 3.4 Medium-term action plan for research and development

Goals	Action Plans	Target
New substrate material for LED and MMIC	• Introduction of plastic material as the foundation for LED manufacturing. This is for flexible LED display • Introduction of glass material for the LED fabrication. This is a preparation for translucent display.	20% of LED device is based on plastic and glass material
Improve yield for compound semiconductor on Silicon	• Improve thermal and crystal matching between compound semiconductor and silicon substrate.	70% yield achievement on compound semiconductor-on-silicon devices.
Increase LED utilisation	• LED lighting penetration towards all street lights, government buildings and household	100% usage on LED lighting by government agencies and 70% usage by household
Low cost LED product	• Innovation in LED substrate, fabrication and packaging	50% cost reduction on LED lamp and luminaire
	• New process for GaN substrate manufacturing	Cheaper GaN based LED device

3.3.3 LONG-TERM ACTION PLAN (2030-2050)

The final term action plan is themed as the "Next Generation Technology", suggesting futuristic product development. This action plans are very crucial to achieve the final scenario. The reason behind this is that being a market leader for the smartphone industry is challenging. Consequently, such companies will face fierce competition. Therefore, the only way to be the market leader is by leading the technological advancement faster than the competitor and at the same time producing low price product. **Table 3.5** presents an action plan for the long term.

Table 3.5 Long-term Action Plan

Goals	Action plans	Target
Next generation LED display utilising quantum dot technology	• Introduction and integration of quantum dot technology into flexible and translucent based LED display.	30% penetration of the new LED display
Phosphorescent Organic LED technology (PhoLED)	• Introduction of phosphorescent organic LED to improve the efficiency.	New Phosphorescent based organic LED with higher efficiency.
Maximum LED utilisation	• Total LED replacement for street lighting, buildings, commercials and household.	• 100% usage on LED lighting • 0% usage on incandescent lamp

3.4 CONCLUSION

Malaysia's participation in the compound semiconductor industry is an encouraging initiative that requires serious effort by various parties. The compound semiconductor industry will continue to grow due to huge demand from the LED display, smartphones, high power applications, and telecommunication industries. Thus, it is vital for Malaysia to gain significant market share in this industry.

The proposed roadmap has targeted interesting scenario in 2050 (the final term). It is planned that by 2050, Malaysia will be the market leader for state-of-the-art smartphone industry and some other consumer electronics businesses. Based on this scenario, several feature, events, action plans and targets have been developed. The roadmap is divided into three terms, namely the first term from 2013 to 2020; medium term from 2020 to 2030; and long-term from 2030 to 2050. **Figure 3.9** demonstrates the complete Malaysia roadmap for the compound semiconductor industry.

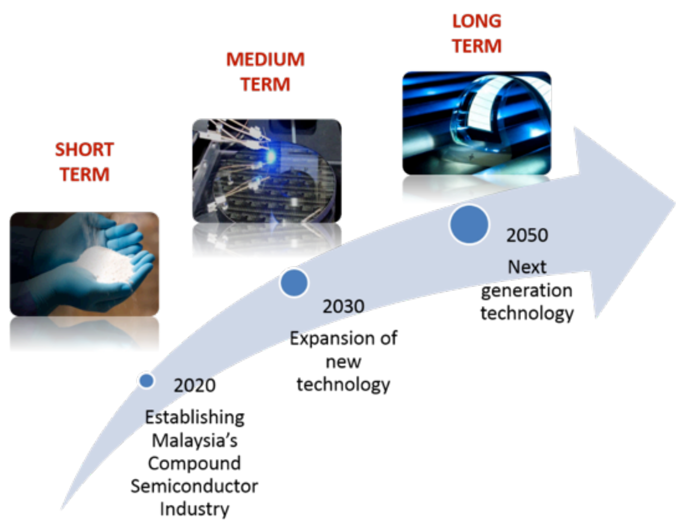


Figure 3.9 Overview of compound semiconductor industry roadmap for Malaysia

CHAPTER 4

ENERGY GENERATION, TRANSMISSION AND DISTRIBUTION BASELINE STUDY: NATIONAL POLICIES, DESIRED OUTCOMES AND INDICATORS, CURRENT STATUS ON LOCAL APPLICATION AND R&D

4.1 DEFINITION OF ELECTRIC POWER SYSTEM

An electric power system is a network of electrical components used to supply, transmit, and use electric power as shown in **Figure 4.1**. One example of an electric power system is the network that supplies a region's homes and industry with power. For sizable regions, this power system is known as a grid and can be broadly divided the following segments: the generators that supply the power; the transmission system that carries the power from the generating centres to the load centres; and the distribution system that feeds the power to nearby homes and industries.

4.2 COMPONENTS OF POWER SYSTEMS

4.2.1 SUPPLIES

All power systems require one or more sources of power. For some power systems, the source of power is external to the system, but for others it is part of the system itself.

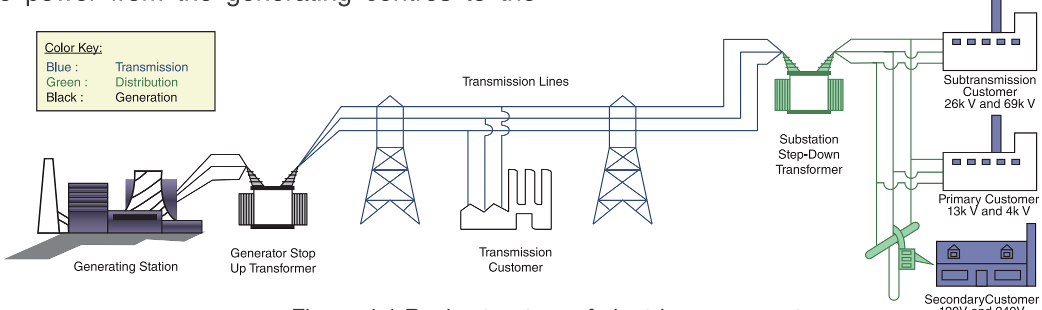


Figure 4.1 Basic structure of electric power system

These internal power sources will be further discussed in the remainder of this section. Batteries, fuel cells, or photovoltaic cells typically supply direct current power. Alternating current power is usually supplied by a rotor that spins in a magnetic field in a device known as a turbo generator. A wide range of techniques have been used to spin a turbine's rotor, from steam heated using fossil fuel (including coal, gas and oil) to nuclear energy, falling water (hydroelectric power), and wind (wind power).

4.2.2 LOADS

Power systems deliver energy to loads that perform a function. These loads range from household appliances to industrial machinery. Most loads expect a certain voltage and (for alternating current devices) a certain frequency and number of phases. The appliances found in the average home, for example, will typically be single-phase, operating at 50 or 60 Hz with a voltage between 110 and 260 Volts (depending on national standards).

4.2.3 CONDUCTORS

Conductors carry power from the generators to the load. In a grid, conductors may be classified as belonging to the transmission system, which carries large amounts of power at high voltages (typically more than 50 kV) from the generating centres to the load centres, or the distribution system, which feeds smaller amounts of power at lower voltages (typically less than 50 kV) from the load centres to nearby homes and industrial plants. Conductors in exterior power systems may be placed overhead or underground. Overhead conductors are usually air insulated and supported on porcelain, glass or polymer insulators. Cables used for underground transmission or building wiring are insulated with cross-linked polyethylene or other flexible insulation.

4.2.4 CAPACITORS AND REACTORS

The majority of the load in a typical AC power system is inductive; that is, the current lags behind the voltage. Reactive power does no measurable work but is transmitted back and forth between the reactive power source and load every cycle. The generators can provide this reactive power, but it is often cheaper to provide it through capacitors; hence, capacitors are often placed near inductive loads to reduce current demand on the power system. Power factor correction may be applied at a central substation or adjacent to large loads. Reactors consume reactive power and are used to regulate voltage on long transmission lines. Reactors installed in series in a power system also limit rushes of current flow. Small reactors are almost always installed in series with capacitors to limit the current rush associated with switching in a capacitor. Series reactors can also be used to limit fault currents.

4.2.5 POWER ELECTRONICS

Power electronics are semiconductor-based devices that are able to switch quantities of power ranging from a few hundred watts to several hundred megawatts. The classic function of power electronics is rectification, or the conversion of AC-to-DC power, power electronics are therefore found in almost every digital device that is supplied from an AC source. High-powered power electronics can also be used to convert AC power to DC power for long distance transmission, in a system known as HVDC. HVDC is used as it has proven to be more economical than similar high voltage AC systems for extreme distances

4.2.6 PROTECTIVE DEVICES

Power systems contain protective devices to prevent injury or damage during failures. The quintessential protective device is the fuse. When the current, through a fuse exceeds a certain threshold, the fuse element melts. This produces an arc across the resulting gap that is then extinguished; interrupting the circuit. In higher-powered applications, the protective relays that detect a fault and initiate a trip are separate from the circuit breaker.

4.3 HISTORY OF MALAYSIAN POWER SYSTEM

4.3.1 BACKGROUND OF MALAYSIAN SCENARIO

Malaysia is a country in the Southeast Asia comprised of Peninsular Malaysia and East Malaysia, separated by the South China Sea. Malaysia's framework in energy development started when petroleum reserves were discovered in the early 1970s. In 17 August, 1974, Petroliam Nasional Berhad (PETRONAS) was incorporated under the Companies Act 1964.

PETRONAS is wholly owned by the Government of Malaysia and is vested with entire ownership and control of petroleum resources in Malaysia through the Petroleum Development Act 1974. Other successive policies include the National Petroleum Policy 1975, National Energy Policy 1979, National Depletion Policy 1980, Four Fuel Diversification Policy 1981, Fifth Fuel Policy 2000, National Biofuel Policy 2006, and most recently, the National Green Technology Policy 2009.

The most important step towards sustainable development was the introduction of the Fifth Fuel Policy in 2000.Biomass, biogas, municipal waste, solar and mini-hydro were recognised as potential RE sources in electricity generation. From that time forward, other new policies have been directed towards utilisation of RE and promotion of energy efficiency in order to reduce over-dependence on fossil fuels while also achieving sustainable national development.

The electricity sector in Malaysia has flourished greatly in the last ten years. The rapid growth has been hand in hand with the nation's economic growth, especially within the industrial and manufacturing sectors. The electricity supply industry is vertically integrated with a generally monopolistic nature, in which a utility company handles all the generation, transmission and distribution of electricity in region. The main utility companies are Tenaga Nasional Berhad (TNB), Sarawak Electricity Supply Company (SESCO), and Sabah Electricity Limited (SESB), each covering the region of Peninsular Malaysia, Sarawak, and Sabah, respectively.

SESB has become one of the subsidiaries of TNB. In all three regions, there are also Independent Power Producers (IPPs) supplying some portion of the electricity supply to the utility companies to transmit to consumers. Several institutions, including the Economic Planning Unit (EPU), Ministry of Energy, Green Technology and Water, the Energy Commission (EC), and Malaysia Energy Centre (*Pusat Tenaga Malaysia*, (PTM)) govern the sector. PTM is an important institution that coordinates various activities, specifically planning and technological research, development, and demonstration in the energy sector (EIA 2013). From the Economic Transformation Programme (ETP), the EPP14 Building Transmission and Distribution Companies are as follows:

a) Transmission and distribution equipment refers to equipment used in generation, transmission and distribution of electricity: switching apparatus, distribution boards, control panels, transformers, cables as well as conductors;

a) Highly values-added and substantial manufacturing of high voltage transmission and distribution equipment; and

a) Build a cluster of transmission and distribution manufacturers in Malaysia: MNCs such as ABB, Siemens and Areva, as well as local companies such as Tenaga Switchgear, Tenaga Cable Industries and Malaysian Transformer Manufacturing.

Hence, a key enabler will be for SIRIM to set up a high-power testing lab to test high-value, high-voltage equipment. Transmission and distribution products must be certified by an accredited short-circuit testing liaison lab to be accepted by the international market. Most such labs are in Europe, such as KEMA in Holland and CESI in Italy. Due to that, the lab should be operated as a joint venture between SIRIM and an internationally accredited lab to be recognised as an accredited member (Economic Transformation Programme: A Roadmap for Malaysia 2010).

4.3.2 ENERGY IN MALAYSIA

The beginnings of the National Grid gradually materialised in 1964 when the Bangsar Power Station was connected to the Connaught Bridge Power Station, with the line subsequently extended to Malacca. By 1965, a plan was set to connect the electricity generating plants spread out all over the country. Plants identified for linking were located at Paka in Terengganu, Temengor, Kenering, Bersia and Batang Padang in Perak, Connaught Bridge, Kapar and Serdang in Selangor, Cameron Highlands in Pahang, Perai in Penang, Port Dickson in Negeri Sembilan, Pergau in Kelantan, Pasir Gudang in Johor and in Malacca.

The central area network with Connaught Bridge Power Station in Klang was the precursor of the energy grid. It also tapped into the Cameron Highlands Hydro scheme from the Sultan Yussuf Power Station and extended into a western network. Late in the 1980s, the loop was finally complete with the placement of Kota Bahru within the grid.

The Central Electricity Board (CEB) was established and began operations on 1 September, 1949. The Board was to become heir to three major projects considered by the Electricity Department following its re-establishment in April 1946, which were the Connaught Bridge Power Station,Cameron Highlands Hydroelectric Project & the development of a National Grid. CEB eventually became the owner of 34 power stations with a generation capacity of 39.88 MW, including a steam power station in Bangsar with a capacity of 26.5 MW, a hydroelectric power station at Ulu Langat with a capacity of 2.28 MW, as well as various diesel powered generators with a total capacity of 11.1 MW.

On 22 June 1965, the CEB of the Federation of Malaya was renamed the National Electricity Board (NEB) of the States of Malaya. By the 80s, the Board was supplying the whole Peninsular with electricity, strategically replacing the Perak River Hydro Electric Power company (PRHEP) and its subsidiary Kinta Electrical Distribution Co. Ltd (KED) in 1982, Penang Municipality in 1976. Meanwhile areas supplied by Huttenbach Ltd in 1964, which included Alor Setar, Sungai Petani, Kulim, Lunas, Padang Serai, Telok Anson, Langkap, Tampin and Kuala Pilah (TNB 2013).

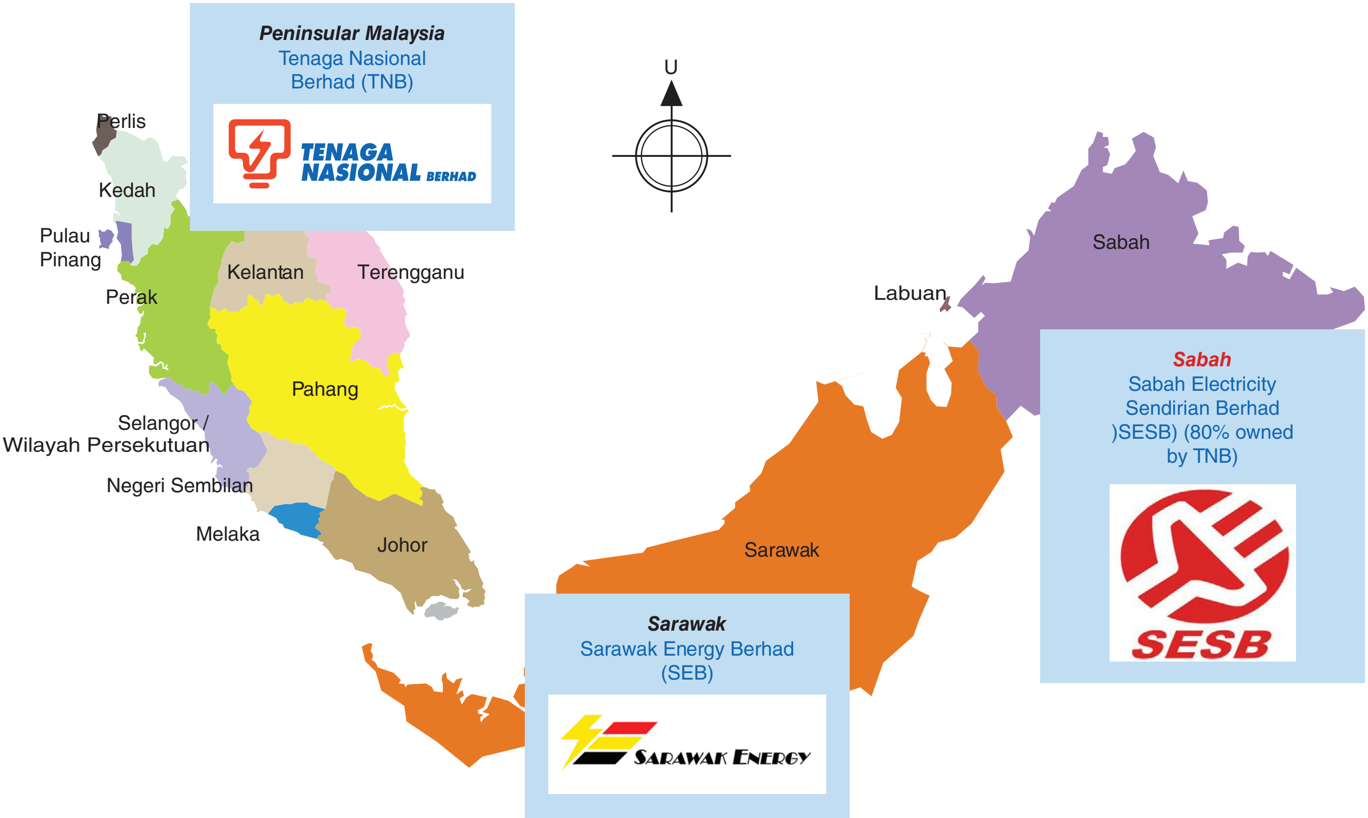
On 4 May, 1988, Prime Minister Mahathir Mohamad announced the government's decision on a policy of privatisation. Two items of legislation were passed to replace the existing Electricity Act and to provide for the establishment of a new corporation. Tenaga Nasional Berhad (TNB) was formed in 1990 under the Electricity Supply Successor Company Act 1990, to succeed the National Electricity Board (NEB) of the states of Malaya.

4.3.3 DISTRIBUTION SYSTEM

Distribution lines of 33 kV, 22 kV, 11 kV, 6.6 kV and 400/230 Volt in the Malaysian distribution network connects to the National Grid via transmission substations where voltages are stepped down by transformers.

4.4 ELECTRIC POWER COMPANIES OF MALAYSIA

The main power companies in Malaysia are TNB, SESB and SEB, as shown in **Figure 4.2**.



TNB (P. Malaysia)	SEB (Sarawak)	SESB (Sabah)
• Operates in Peninsular Malaysia • Total generation capacity is 21,051 MW (2010) • Customer is 7,593,684 • Max demand: 15,072MW • Gen mix (2010): - 54% gas - 40% coal - 5.2% hydro - 0.2% distillate	• Operates in Sarawak • Total generation capacity is 21,051 MW (2010) • Customer is 499,618 • Max demand: 1036 MW • Gen mix (2009): - 53% gas - 34% coal - 8% hydro - 5% diesel	• Operates in Sabah • Total generation capacity is 866.4 S MW (2010) • Customer is 413,983 • Max demand: 760 MW • Gen mix (2009): - 57% gas - 31% coal - 9% hydro - 3% biomass

Note: Electricity supply industry in Malaysia is a fully regulated. TNB, SEB and SESB are vertically integrated and operate along with independent power producers (IPPS)

Figure 4.2 General profiles of power utilities in Malaysia

4.4.1. TENAGA NASIONAL BERHAD (TNB)

Tenaga Nasional Berhad (TNB) is the largest Electric utility company in Malaysia, and also the largest power company in Southeast Asia, with RM69.8 billion worth of assets. It serves over seven million customersthroughout Peninsular Malaysia and also the eastern State of Sabah through Sabah Electricity Sdn Bhd, TNB's core activities are the generation, transmission and distribution of electricity. Other activities include repairing, testing and maintaining power plants, providing engineering, procurement and construction services for power plants related products, assembling and manufacturing high voltage switchgears, coal mining and trading. Operations are carried out in Malaysia, Mauritius,Pakistan, India and Indonesia.

The Central Electricity Board (CEB) was established and came into operation on 1 September, 1949. The Board become heir to three major projects considered by the Electricity Department following its re-establishment in April 1946, namely the Connaught Bridge Power Station of the Cameron Highlands Hydroelectric Project and the development of a National Grid. CEB eventually became the owner of 34 power stations with a generation capacity of 39.88 MW, including a steam power station in Bangsar with a capacity of 26.5 MW, a hydroelectric power station in Ulu Langat with a capacity of 2.28 MW, as well as various diesel powered generators with a total capacity of 11.1 MW.

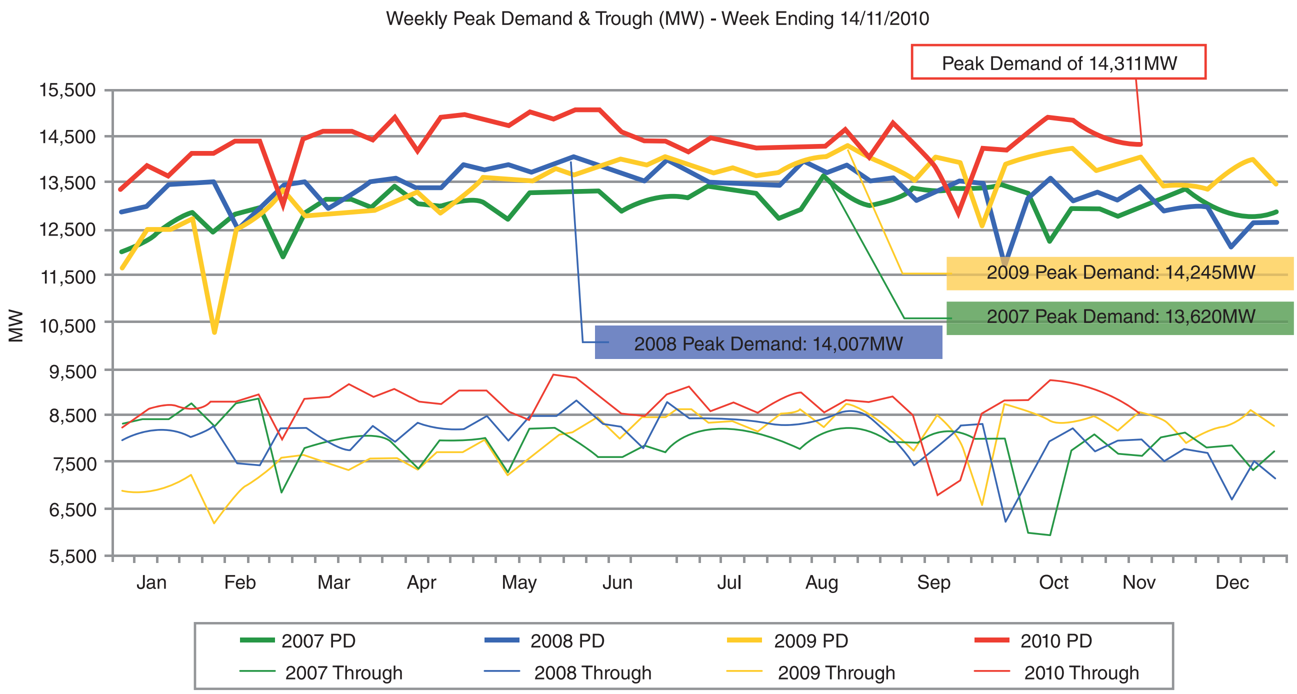


Figure 4.3 Overview of TNB System: Trend of demand growth (2007 ~ 2010)

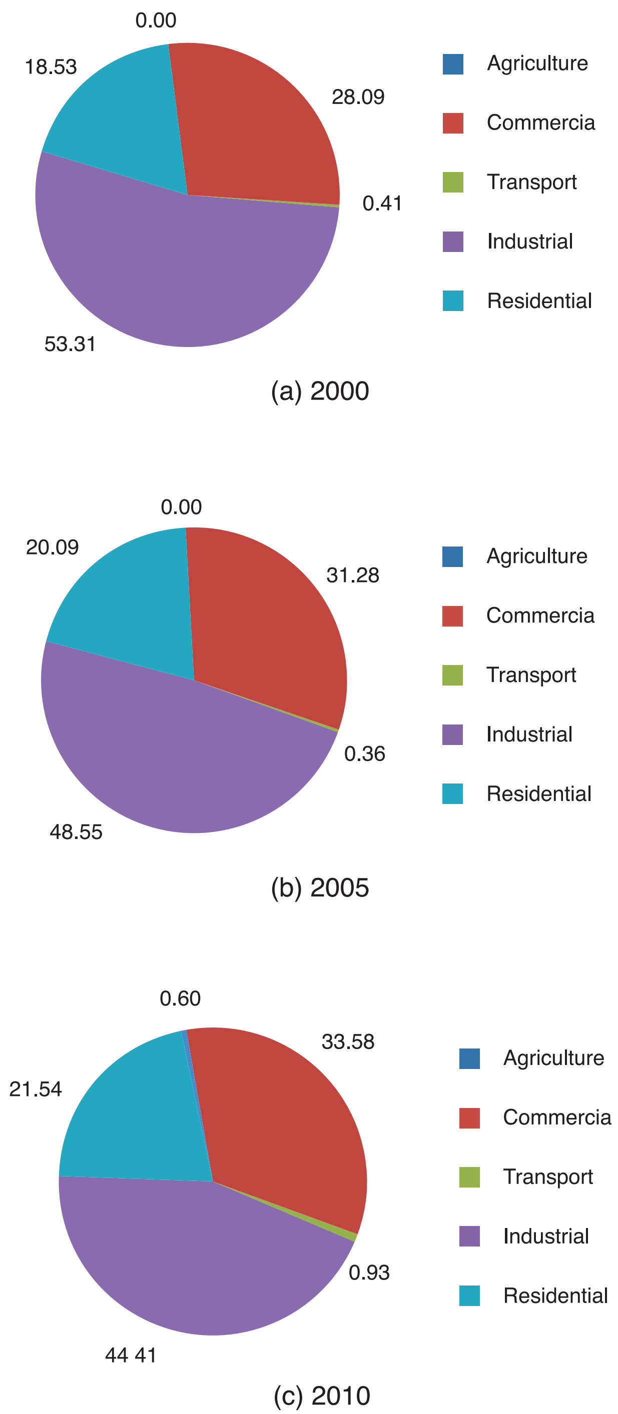


Figure 4.4 Final electricity consumption (ktoe)

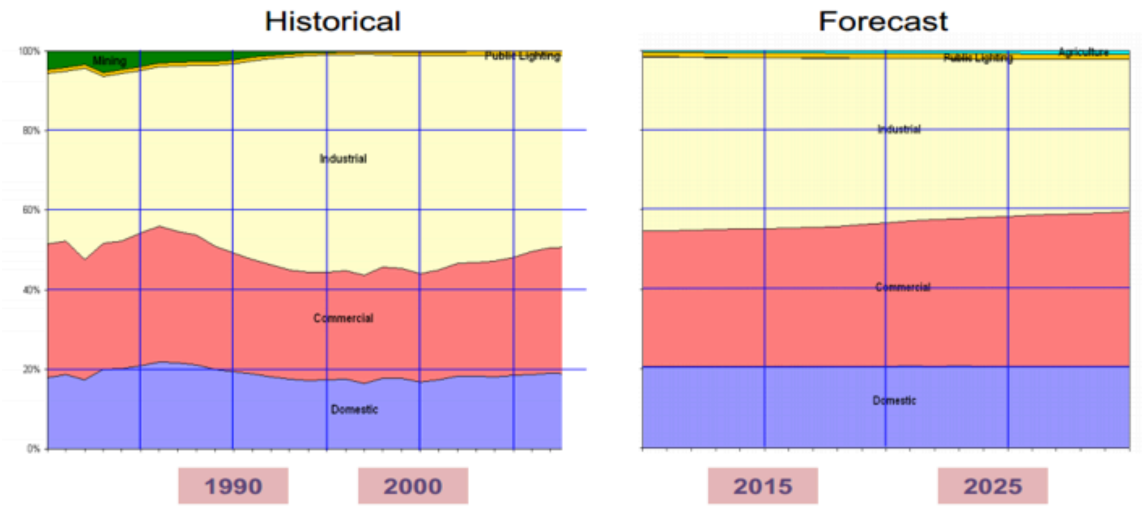


Figure 4.5 Overview Of TNB System:
Electricity consumption by customer type (1990~2030)

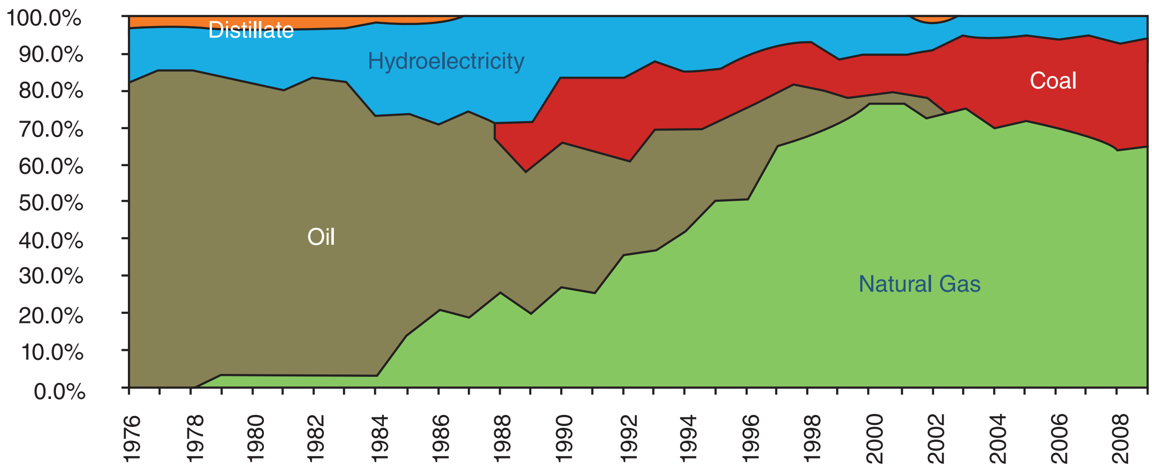


Figure 4.6 Overview of TNB System: Trend of power generation mix (1976~2008)

On 22 June 1965, the CEB of the Federation of Malaya was renamed as the National Electricity Board (NEB) of the States of Malaya. By the 80s, the Board was supplying electricity to the whole of peninsular; while strategically replacing the Perak River Hydro Electric Power company (PRHEP) and its subsidiary Kinta Electrical Distribution Co. Ltd. (KED) in 1982. It also took over the supply inthe Penang Municipality in 1976, including areas supplied by Huttenbach Ltd in 1964, namely Alor Setar, Sungai Petani, Kulim, Lunas, Padang Serai, Telok Anson, Langkap, Tampin and Kuala Pilah.

On 4 May 1988, the Prime Minister of Malaysia, Mahathir Mohamad, announced the government's decision on a policy of privatisation. Two pieces of legislation were passed to replace the existing Electricity Act and to provide for the establishment of a new corporation. Tenaga Nasional Berhad (TNB) was formed in 1990 by the Electricity Supply Successor Company Act 1990, to succeed the NEB of the states of Malaya.

4.4.1.1 GENERATION DIVISION

The generation division owns and operates thermal assets and hydroelectric generation schemes in Peninsular Malaysia and an Independent Power Producer (IPP) operating in Pakistan. In the Peninsular, it has a generation capacity of 11,296 MW. Among plans to expand its generation capacity include increasing hydroelectric generation by 2015 and commissioning the first nuclear power plant in Malaysia by 2025 if the government decides to include nuclear as an acceptable energy option.

4.4.1.2 TRANSMISSION DIVISION

Currently, the TNB Group has a complete power supply system, including the National Grid which is energised at 132, 275 and 500 kilovolt (kV), with its tallest electricity pylon in Malaysia and Southeast Asia being the Kerinchi Pylon located near Menara Telekom, Kerinchi, Kuala Lumpur.

The National Grid is linked via 132 kV HVAC and 300 kV HVDC interconnection to Thailand and 230 kV cables to Singapore.TNB, through its subsidiaries, is also involved in the manufacturing of transformers, high voltage switchgears and cables, consultancy services, architectural, civil and electrical engineering works and services, repair and maintenance services and fuel undertakes research and development, property development, and project management services. TNB also offers higher education through its university, Universiti Tenaga Nasional (UNITEN) (TNB 2013).

4.4.1.3 DISTRIBUTION DIVISION

The Distribution division conducts the distribution network operations and electricity retail operations of TNB. The division plans, constructs, operates, performs repairs and maintenance, and manages the assets of the 33 kV, 22 kV, 11 kV, 6.6 kV and 415/240 Volt in the Peninsular Malaysia distribution network. Sabah Electricity provides the same function in the State of Sabah. To conduct its electricity retailing business, it operates a network of State and area offices to purchase electricity from embedded generators, market and sell electricity, connect new supply, provide counter services, collect revenues, operate call management centres, provide supply restoration services, and implements customer and government relationships.

4.4.2 SABAH ELECTRICITY

Sabah Electricity Sdn Bhd (SESB) is an electrical company that generates, transmits and distributes electricity mainly in Sabah and Federal Territory of Labuan. It supplies electrical power to 413,983 customers distributed over a wide area of 74,000 km^2. 82.8% of the customers are domestic customers consuming only 28.8% of the power generated. This company employs more than 2,300 employees and the main stakeholders of this company are Tenaga Nasional Berhad (TNB) (80%) and Sabah State Government (20%). Electricity started in Sabah as early as 1910 supplied by 3 separate organisations.

In 1957, these three organisations combined to form the North Borneo Electricity Board. When North Borneo joined Malaysia in 1963 and changed its name to Sabah, this entity was renamed Sabah Electricity Board. On 1st of September, 1998, Sabah Electricity Board was privatised and became Sabah Electricity Sdn Bhd

4.4.2.1 GENERATION CAPACITY

The total generation capacity of SESB is 866.4 MW, 50.3% of the total units generated are purchased from the independent power producers (IPP). The SESB installed capacity (excluding IPP) of the Sabah Grid, which supplies electricity for major towns from Federal Territory Labuan to Tawau, is 430.9 MW and the maximum demand is 760 MW (as of June 2010).

The East Coast Grid 132 kV Transmission Line connecting the major towns in the East Coast has an installed capacity of 333.02 MW and the maximum demand is 203.3 MW. The forecast demand growth of electricity is around 7.7% per annum up to the year 2010 and the electricity demand is expected to reach 1,500 MW by the year 2020. In order to support the growing demand, various generation, transmission, and distribution projects will be implemented.

A fully integrated grid connecting the West Coast Grid to the East Coast Grid was completed on 28 July, 2007. About 90% of customers are now connected to this integrated grid. The following is asummary of the list of power plants available:

- Number of Station: 37 (including 12 IPP excluding BELB stations)
- Power generated for FY 2010 up to July 2010: 1,279.6 GWh (SESB) & 3,074.8 GWh (IPP)

4.4.2.2 MAJOR POWER STATIONS

Table 4.1 Major Power Stations

Name and location	Station Type	Engine Configuration	Capacity
SJ Patau-Patau	Thermal	2 ´ 32MW, 1 ´ 33MW, 1 ´ 15 MW	99.0 MW
SJ Hydro Tenom-Pangi	Hydroelectric	3 ´ 22 MW	66.0 MW
SJ Melawa	Thermal	3 ´ 8 MW, 1 ´ 20 MW	31.4 MW
SJ Tawau	Thermal	4 ´ 8 MW, 1 ´ 12 MW, 1 ´ 20 MW	40.0 MW
SJ Sandakan	Thermal	2 x 8.5 MW, 2 x 14 MW, 2 x 19 MW	72.0 MW

4.4.3 SARAWAK ENERGY

Sarawak Energy (formerly Syarikat SESCO Berhad or Sarawak Electricity Supply Corporation, SESCO) is the energy company responsible for the generation, transmission, and distribution of electricity for the Sarawak State in Malaysia. The State Government of Sarawak owns it.

Sarawak Energy provides electricity to about 382 000 customers. Over the last four years, sales of electrical grew at an average of 8% per annum. Sarawak Energy has slightly over 2000 employees. SESCO is owned 51.6% by the Sarawak State Government and 45% by the Sarawak Enterprise Corporation Berhad (SECB). The Corporation's total assets currently stand at around RM4.0 billion.

4.4.3.1 GENERATION CAPACITY

Currently, throughout the State, thirty-six power stationshave beenstrategically established with a total of installed capacity of 1315 MW; comprising of 5% diesel engine, 24.6% gas turbines, 36.5% coal-fired power plant, 25% Combined Cycle Power Station and 7.6% hydro turbines. The major towns are connected to via a 275/132 kV State Transmission Grid. The SESCO generates electricity mainly from two major types of plants, namely hydroelectric plants and thermal plants.

4.4.3.2 HYDROELECTRIC POWER PLANTS

There is one major hydroelectric scheme with an installed generating capacity of 100 MW and one dam in operation - the Batang Ai hydroelectric scheme. It comes equipped with the followig:

100 MW installed capacity:

Batang Ai Dam- 4 ´ 25 MW = 100 MW.

4.4.3.3 THERMAL POWER PLANTS

There are 35 thermal power plants and diesel-electric plants with installed generating capacity of 1215 MW in operation. The selected major plants are as follows:

- Tun Abdul Rahman Power Station, Kuching - 46 MW Gas Turbine and 68 MW Diesel engine.
- Miri power station, Miri - 99 MW, Open Cycle Gas Turbine
- Bintulu power station, Bintulu- 330 MW, Combined Cycle Power Plant
- Tanjung Kidurong Power Station, Bintulu- 192 MW, Open Cycle Gas Turbine
- Sejingkat Power Station, Kuching -210 MW, coal-fired power station (phase II)
- Mukah Power Station, Mukah- 2´135 MW, Coal Fired Power Station

4.4.4 MALAKOFF CORPORATION BERHAD

This is a Malaysian power company that generates and sells power as an independent power producer to Tenaga Nasional for uploading onto the Malaysia. Malakoff generates electricity mainly from two major types of plant - steam turbine thermal plants and gas turbine plants. In addition, the company owns and operates four power plants:

- The Lumut Power Station in Segari, Perak with 1,303 MW capacity. Malakoff has 93.75% equity interest in the plant owner Segari Energy Ventures Sdn Bhd (SEV).
- The Lumut GB3 Power Station in Segari, Perak with 640 MW has 75% equity in plant owner GB3 Sdn Bhd.
- The Prai Power Station, Butterworth, Pulau Pinang, with 350 MW held through its wholly owned subsidiary, Prai Power Sdn Bhd.
- The Tanjung Bin Power Station, Tanjung Bin, Johor with 2,100 MW has 90% of shares in plant Tanjong Bin Power Sdn Bhd (formerly SKS Power Sdn Bhd).The company also has equity on two power stations, but the capacities of these plants are listed under the majorityshareholder.
- The Port Dickson Power Station, at Tanjong Gemok, near Port Dickson, Negeri Sembilan - a 440 MW open cycle peaking power plant through a 25% equity interest in Port Dickson Power Berhad, held through Malakoff's wholly owned subsidiary, Hypergantic Sdn Bhd
- The Kapar Power Station, Kapar, Selangor - a 2,420 MW coal, oil and gas-fired plant, with a 40% share. Malakoff acquired a 50% share in the 420
- MW Australian Macarthur Wind Farm in 2013. The company's total generation capacity of 4,393 MW.

4.4.5 POWERTEK

Powertek Sendirian Berhad is a subsidiary of Tanjong PLC, it generates and sells power as an independent power producer to Tenaga Nasional, for uploading onto the National Grid, Malaysia.

4.4.5.1 GENERATION CAPACITY

The total generation capacity is 1,490 MW. The *Powertek* generates electricity mainly from gas turbine plants. *Powertek* and its subsidiaries own and operate three power plants in Melaka, with a total installed generating capacity of 1,490 MW, comprising:

- Telok Gong Power Station 1, Telok Gong - 440 MW open cycle gas turbine (OCGT), owned and operated by Powertek Berhad;
- Telok Gong Power Station 2, Telok Gong - 720 MW combined cycle gas turbine (CCGT), owned and operated by Panglima Power Sdn Bhd; and
- Tanjong Kling Power Station, Tanjong Kling - 330 MW combined cycle gas turbine owned and operated by subsidiary, Pahlawan Power Sdn Bhd.

4.4.6 SABAH GAS INDUSTRIES

Sabah Gas Industries Sdn Bhd was a State-owned holding company based in Labuan, Malaysia. It was established in 1982 by the Government of Sabah for the downstream operations of Sabahan natural gas resources. The company owned and operated a 660,000-tonne per year methanol plant, a 600,000-tonne per year sponge iron factory, and a 79 MW natural gas-fired power station, all commissioned in 1984 after the gas pipeline from the offshore gas fields became operational.

The industries were supplied with natural gas from the Erb West and Samarang offshore fields. In the beginning of the 1990s, due to financial difficulties, the company was put up for privatisation. In 1992, the methanol plant was sold to PETRONAS and operates today as PETRONAS Methanol (Labuan) Sdn Bhd. The power station was sold to Sabah Electricity. The sponge iron factory was acquired by the affiliated companies of the today's Lion Group. The plant operates today as Antara Steel Mills Sdn Bhd.

4.4.7 YTL POWER

YTL Power, a subsidiary of YTL Corporation, generates and sells power as an independent power producer to Tenaga Nasional for uploading onto the National Grid, Malaysia.YTL Power is the builder, owner and operator of two power plants for a concession period of 21 years following Malaysia's privatisation policy.

As the first independent power producer licensed in Malaysia, its power purchase agreement has the best terms offered, which include a take-or-pay clause; which requires Tenaga Nasional to pay a guaranteed amount whether the power is uploaded or not.In December 2010, YTL Power acquired 30% stake in Eesti Energia's oil shale development project in Jordan.

4.4.8 RANHILL BERHAD

Ranhill Berhad is a provider of construction, engineering and infrastructure management services with assets and business activities in the following sectors: Environment, Power, Infrastructure and Petrochemical. Ranhill traces its origins to 1955, when John Rankine and John Hill formed Rankine & Hill in Sydney. Rankine & Hill ventured into Malaysia and opened an office in Kuala Lumpur in 1961. Following that, Ranhill Bersekutu Sdn Bhd was established in 1973 with Rankine & Hill's Malaysian partners.

In 1981, the Company's Malaysian partners took over the controlling stake in the business, transferring Ranhill Bersekutu to full Malaysian ownership. Since establishing its presence in 1973 as engineering consultants, it expanded first into engineering, procurement and project management, then into turnkey construction, facility management, development and ownership of projects. Ranhill now focuses on the industrial sectors such as oil and gas, power, water and infrastructure. In 1996, it expanded its services to include construction when the company executed its first turnkey EPC project – the Sri Gading Water Treatment Plant in Johor. In 2001, Ranhill Berhad became a public company and was listed on the Main Board of Bursa Malaysia Securities Berhad. Since its listing, Ranhill has moved into oil and gas production, infrastructure investment, power plant design, power plant engineering, and industrial water treatment.

Ranhill plans to drill for oil in West Java, Indonesia. Ranhill, via its 60% investment in a joint venture company with PT Bumi Parahyangan Ranhill Energia Citarum and secured the oil block in October 2006. Ranhill's current oil and gas investments include a gas production field about 15 km north of Citarum (Jatirarangon TAC), an exploration block in South Sumatra (Jambi Batu Gajah PSC) and two exploration blocks in the Philippines (SC49 and SC64). In 2004, the oil consortium PetroDar awarded a contract to a joint venture between Ranhill and Petroneeds for Engineering, Procurement, Construction, and Commissioning (EPCC) of an oil facility in Sudan's Melut Basin.

The joint venture is 55% owned by Ranhill. The company saw the contract as an opportunity to expand its EPCC work. To illustrate, when Ranhill's financial year ended on 30 June 2006, more than 60% of its RM9.3 billion order book came from overseas, including a housing contract worth RM7.4 billion in Libya and hydropower plant in Pakistan.

4.5 POLICIES, INDICATORS AND OUTCOME

4.5.1 ENERGY POLICY OF MALAYSIA

The energy policy of Malaysia is determined by the Malaysian Government, and they address issues of energy production, distribution, and consumption. The Department of Electricity and Gas Supply acts as the regulator while other players in the energy sector include energy supply and service companies, research and development institutions and consumers. Government-linked companies PETRONAS and Tenaga Nasional Berhad are major players in Malaysia's energy sector.

Apart from that, governmental agencies that contribute to the policy are the following:

- Ministry of Energy, Green Technology and Water
- Energy Commission (Suruhanjaya Tenaga),
- Malaysia Energy Centre (Pusat Tenaga Malaysia).

Among the documents that the policy is based on are the 1974 Petroleum Development Act, 1975 National Petroleum Policy, 1980 National Depletion Policy, 1990 Electricity Supply Act, 1993 Gas Supply Acts, 1994 Electricity Regulations, 1997 Gas Supply Regulation. The 2001 Energy Commission Act. The Ministry of Energy, Green Technology and Water identified three principal energy objectives that would be instrumental in guiding the development of its energy sector.

4.5.1.1 SUPPLY

The purpose of supply policy is to ensure the provision of adequate, secure, and cost-effective energy supplies through developing indigenous energy resources both non-renewable and renewable energy resources using the latest cost options and diversification of supply sources both from within and outside the country. In pursuit of the supply objective, policy initiatives, particularly with respect to crude oil and natural gas. We have aimed at both extending the life of domestic non-renewable energy resources, as well as diversification away from oil dependence to include other forms of energy sources.

4.5.1.2 UTILISATION

The purpose of utilisation policy is to promote the efficient utilisation of energy and discourage wasteful and non-productive patterns of energy consumption. The policy's approach to realise this objective is to rely heavily on the energy industry and consumers to exercise efficiency in energy production, transportation, energy conversion and consumption through the implementation of awareness programmes. The demand side of management initiatives by utilities, particularly through tariff incentives, have had a certain impact on efficient utilisation and consumption. Furthermore, government initiatives to encourage cogeneration are also aimed at promoting an efficient method for generating heat energy and electricity from a single energy source.

4.5.1.3 ENVIRONMENTAL

The purpose of environmental policy is to minimise the negative impacts of energy production, transportation, conversion, utilisation and consumption on the environment. The environment objective has seen limited policy initiatives in the past. All major energy development projects are subjected to the mandatory environmental impact assessment requirement. Environmental consequences, such as emissions, discharges, and noise are subjected to the environmental quality standards like air quality and emission standards (Statistical Review of World Energy 2013).

4.5.1.4 RENEWABLE ENERGY POLICY

The Malaysian government is seeking to intensify the development of renewable energy, particularly biomass, as the 'fifth fuel' resource under the country's Fuel Diversification Policy. The policy, which was set out in 2001, had a target of RE providing 5% of electricity generation by 2005, equal to between 500 and 600 MW of installed capacity. This policy has been reinforced by fiscal incentives, such as investment tax allowances and the SREP, which encourages the connection of small renewable power generation plants to the national grid.

SREP enables renewable projects with up to 10 MW of capacity to sell their electricity output to TNB under a 21-year license agreement. Apart from that, numerous applications for the programme have been received, mainly involving biomass, and of these over half are for palm oil waste. In 2005, there were 28 approved biomass projects involving the installation of 194 MW of grid-connected capacity. There were also four approved landfill gas-based projects, with 9 MW of capacity, and 18 mini hydro-electric projects offering 69.9 MW of total capacity (Statistical Review of World Energy 2013).

4.5.1.5 BIOFUEL POLICY OF MALAYSIA

The biofuel policy of Malaysia is based on Malaysia's National Biofuel Policy document.Yanmar, a Japan-based global manufacturer of diesel engines, has planned to build a research facility in Malaysia to conduct research on the development of palm oil biodiesel. It intends to develop and test biodiesel for the industrial diesels it develops for its machines and generators. The research facility will be established in Kota Kinabalu.

4.5.1.6 PRODUCTION AND CONSUMPTION

Traditionally, energy production in Malaysia has been based around oil and natural gas. Malaysia currently has 13 GW of electrical generation capacity. According to Suruhanjaya Tenaga, the power generation capacity connected to the Malaysian National Grid is 19,023 MW, with maximum demand of 13,340 MW as of July 2007. The total electricity generation for 2007 is 108,539 GW·h, with a total consumption of 97,113 GW·h, or 3,570 kW·h per capita. The generation fuel mix is 62.6% gas, 20.9% coal, 9.5% hydro and 7% from other forms of fuel.In 2007, for instance, the country as a whole consumed 514 thousand barrels (23.6 million tonnes) of oil daily against a production of 755 thousand barrels (34.2 million tonnes) per day.

However, Malaysia only has 33 years of natural gas reserves and 19 years of oil reserves, meanwhile the demand for energy is increasing. Due to this, the Malaysian government is expanding into renewable energy sources. Currently 16% of Malaysian electricity generation is hydroelectric, the remaining 84% being thermal. The oil and gas industry in Malaysia is currently dominated by state-owned PETRONAS, and the energy sector as a whole is regulated by Suruhanjaya Tenaga, a statutory commission who governs the energy in the Peninsular and Sabah, under the terms of the Electricity Commission Act of 2001.

Table 4.2 Peninsular Malaysia Historical Electricity Production and Consumption - All Units in Megawatts (Energy Commission Annual Report)

Year	Production Capacity			Maximum Demand
	TNB Production Capacity	IPP Production Capacity	Total Production Capacity	
2005	6346	11277	17623	12493
2006	6346	11977	18323	12990
2007	6346	13377	19723	13620
2008	6436	13377	19723	14007
2009	7040	14777	21817	14245

Table 4.3 Sabah Historical Electricity Production and Consumption Data - All Units in Megawatts (Energy Commission Annual Report)

Year	Production Capacity	Maximum Demand
2005	660	548
2006	708	594
2007	706	625
2008	812	673
2009	903	719

4.5.1.7 ENERGY EFFICIENCY

Industrial consumers use about 40% of primary energy, as well as about 55% of the electricity (which consumes about 38% of primary energy) used in Malaysia. This means that industrial consumers use about 60% of the total energy used in Malaysia. The Malaysian Energy Commission has set up various energy efficiency programmes.

4.5.1.8 FEED-IN TARIFFT

The Malaysian government is seeking to intensify the development of renewable energy, particularly biomass, as the fifth fuel resource under the country's Fuel Diversification Policy. The policy, which was set out in 2001, had a target of renewable energy providing 5% of electricity generation by 2005; equal to between 500 and 60 MW of installed capacity.

The policy has been reinforced by fiscal incentives, such as investment tax allowances and SREP, which encourages the connection of small renewable power generation plants to the grid. The SREP allows renewable projects with up to 10 MW of capacity to sell their electricity output to TNB, under 21-year license agreements. Numerous applications for the programme have been received, mainly involving biomass, and of these over half are for palm oil waste. In 2005 there were 28 approved biomass projects involving the installation of 194 MW of grid-connected capacity. There were also four approved landfill gas-based projects, with 9 MW of capacity, and 18 mini hydroelectric projects offering 69.9 MW of total capacity.

The establishment of MESITA (Malaysia Electricity Industry Trust Account) in 1997 has successfully catalysed the rural electrification programme. Managed by the Ministry of Energy, Water and Communications (MEWC), it is an innovative trust fund in whichall the major Independent Power Providers (IPPs) in Peninsular Malaysia. Meanwhile Sabah contributes about 1% of their annual pre-tax profit for rural electrification (including promotional activities), renewable energy and energy efficiency projects and training.

4.5.1.9 OTHER POLICY

Green technology is the development and application of products, equipment and systems used to conserve the natural environment and resources, which minimises and reduces the negative impact of human activities. Green technology refers to products, equipment, and systems which satisfy the following criteria:

- It minimises the degradation of the environment;
- It has zero or low Greenhouse Gas (GHG) emission. Thus, it is safe for use and promotes health, while improving environment for all forms of life.
- It conserves the use of energy and natural resources.
- It promotes the use of renewable resources.

National energy policy (1979)

- To ensure adequate, secure and cost-effective energy supplies using both non-renewable and renewable energy resources
- To promote efficient utilisation of energy
- To minimise negative impacts on the environment in the energy supply chain

National Depletion Policy (1980)

- To prolong lifespan of Malaysia's oil reserves for future security and stability in fuel supply

Four Fuel Policy (1981)

- To pursue balance utilisation of oil, gas, hydro and coal

Five Fuel Policies (2001)

- To place Renewable Energy (RE) as the fifth fuel in the energy supply mix

National Green Technology Policy (2009)

- To place green technology as the driver to accelerate the national economy and promote sustainable development

4.5.2 INDICATOR AND OUTCOME

A total of 14 energy indicators have been developed in the context of sustainable development in Malaysia through the identification of energy policy priority areas. The identified priority areas are as follows:

- ensuring sufficiency and cost-effectiveness of energy supply;
- improving energy efficiency;
- increasing utilisation of renewable energy;
- minimising the energy impact on the environment; and
- improving the quality of life in term of social well-being.

Furthermore, energy indicators are divided into social, economic, and environmental dimensions. Using the developed energy indicators thus assesses the energy policy priority areas. In order to develop energy indicators for sustainable development that are in line with the country's energy policies, the energy priority areas were described according to the dimensions of sustainable development and energy related topics. A total of 14 indicators have been developed as a core set of energy indicators, as shown in **Table 4.4**.

Table 4.4 Dimensions of sustainable development and Malaysian energy policy priorities

Dimensions of sustainable development	Energy priority areas	Energy-related topics	Relevant energy indicators	
Social	Improving quality of life in term of social well-being	Accessibility	Rural electrification coverage by region (per cent)	
		Affordability	Share of electricity spending in total household expenditure for different income groups (%)	
		Disparities	Share of electricity subsidy received among different income groups (per cent)	
Economic	Ensuring sufficiency and cost-effectiveness of energy supply; Improving energy efficiency; Increasing utilisation of renewable energy	Overall use	Energy use per capita	
		Overall productivity	Energy use per GDP	
		Production	Rate of self-sufficiency	
		End use	Share of sectoral energy demand total energy consumption	
			Sectoral energy intensities	
		Diversification (Fuel Mix)	Fuel shares in energy and electricity	
			Renewable energy share in energy and electricity	
		Prices	End-use energy prices by fuel	
		Fuel reserves	Reserves-to-production-ratio	
Environment	Minimising the energy impact on the environment	Climate change	GHG emissions from energy consumption per unit of GHG	
		Air quality	Shares of emission loads from energy sector in air pollutant emissions (%)	

4.5.2.1 INDICATOR ASSESMENT

a. Rural electrification coverage by region (per cent)

As shown in **Figure 4.7**, average rural electrification coverage in Malaysia reached about 93% in 2004. However, there are still about 30% and 20% of rural households in Sabah and Sarawak that have no access to electricity, respectively. The government has set targets to improve the accessibility of modern energy services, especially in the rural areas of Sabah and Sarawak (EPU 2006).

Figure 4.7 Rural electrification coverage areas by region, data and projections (%)

b. Share of electricity in total household expenditure for different income groups (per cent)

Figure 4.8 indicates that the share of electricity expenditure for each income group hadincreased by 1998, as compared to 1994 (TNB 1990; TNB 1997). While a part of this is due to the 10% increase in electricity tariffs, the increment could also be due to the improved living standards, which made electricity more affordable. From 1998 to 2005, electricity tariffs remained unchanged but the share of electricity increased significantly, especially among the lowest income group. This confirms the increased affordability of electricity, and suggests that the standard of living for the poor in the country has also improved.

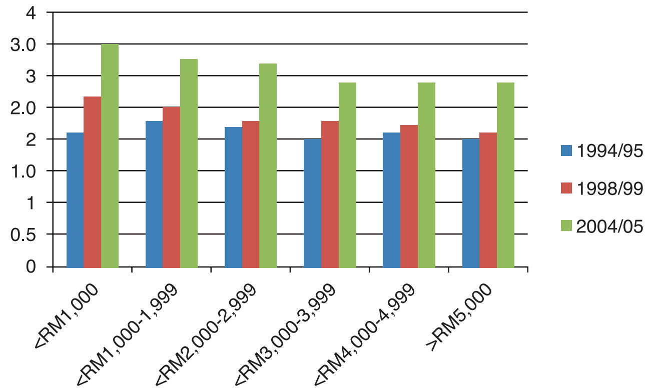


Figure 4.8 Share of Electricity Spending in Total Household Expenditure For different income groups (%)

c. Share of electricity subsidy received among different income groups (per cent)

As shown in **Figure 4.9**, the richest group experiencedthe highest tariff subsidies in both the years of 1998/99 and 2004/04. The overall distribution of tariff subsidies remained economically progressive. Note that electricity tariffs remained unchanged from 1997 to May 2006. The latest tariff adjustment was made in June 2006. On average the adjusted tariff wasincreased by about 12%. However, consumers that consume less than 200 kWh per month or monthly electricity expenditure less than RM43.60 (April 2008: USD1 = RM3.19) werenot affected by the new tariff.

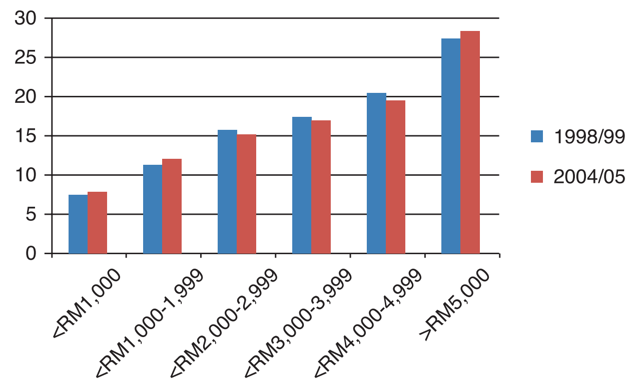


Figure 4.9 Share of electricity subsidy received among different income groups, 1998/99 and 2004/05 (%)

d. Energy use per GDP (toe/RM Million)

Figure 4.10 shows that the trend of final energy intensity is becoming stable in the years 2001 - 2006. However, the intensity of electricity consumption continues to increase, though at a slower pace after 1998. This pattern, in which electricity use grows faster than all energy, is also seen in many other countries, and suggests both increased electrification of society and new end uses (such as air conditioning, computers and electronic equipment) that require electricity. Hence, more efficient use of electricity is desirable in Malaysia, as in other countries.

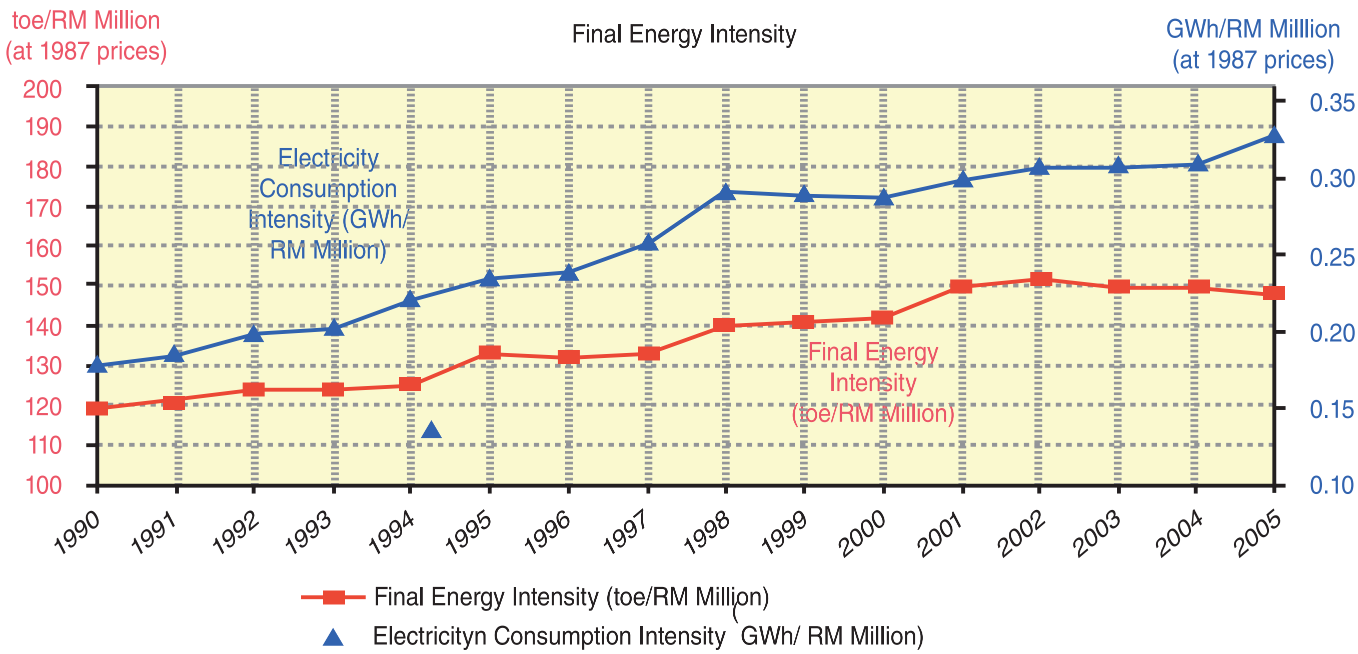


Figure 4.10 Final energy intensity (toe/RM Million) and Electricity Consumption Intensity (GWh/RM Million

The final energy intensities of selected countries are shown in **Figure 4.11**. The Economic Planning Unit of Malaysia has taken Denmark, Germany, and Republic of Korea as the benchmark for energy efficiency in Malaysia (EPU 2006). Malaysian energy intensity is about the same as that of Korea and the USA, but is higher than almost all other countries shown in the **Figure 4.10**. This comparison suggests that Malaysian economy should be more energy efficient.

e. Rate of self-sufficiency (per cent)

Figure 4.12 shows that Malaysia is able to meet the energy needs at current production levels (greater than 100%), self-sufficiency rates are decreasing. Hence, policy measures in improving both production and consumption aspects need to be made to secure the nation from becoming an energy net importer.

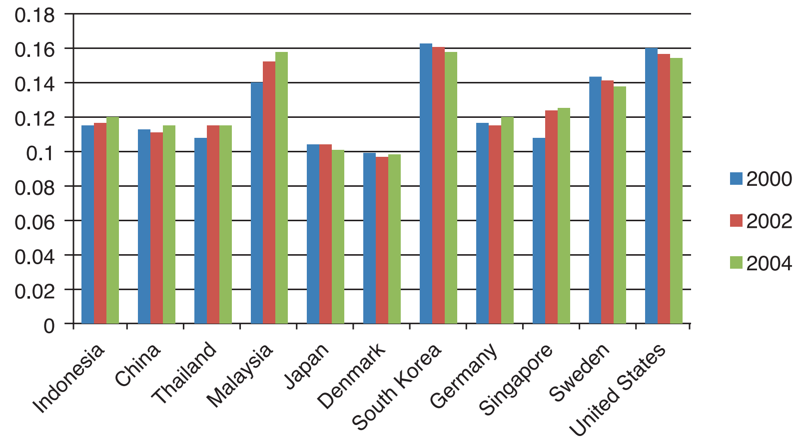


Figure 4.11 Final energy intensities for some of the selected countries (Total final energy consumption/GDP using purchasing power parities) (toe/'000 2000 USD)

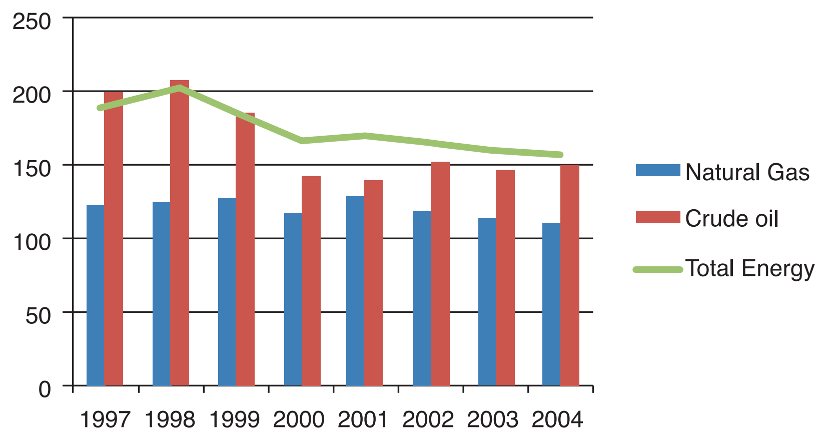


Figure 4.12 Rate of energy self-sufficiency (%)

f. Shares of sectorial energy demand in total energy consumption (per cent)

As shown in **Figure 4.13**, transport and industrial sectors are the major energy consuming sectors, and the total energy use in these two sectors accounted for about 80% of the total energy consumption in the country. The transport sector has consumed the largest share of total energy consumption since 1999. The annual growth rate of registered vehicles from 1999 to 2004 was about 7.7% (DOE 2005; DOS 2005).

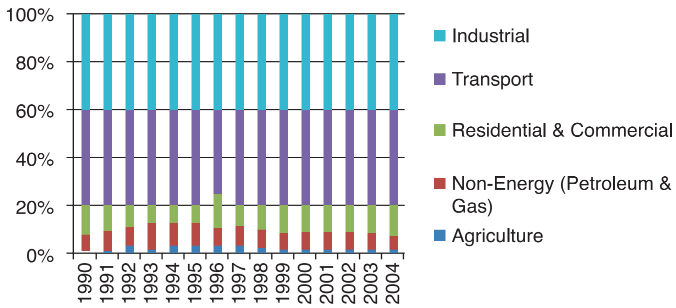


Figure 4.13 Share of sectoral energy demand in total energy consumption,1990 to 2004 (%)

Figure 4.14 indicates that the major electricity consuming sectors are "residential & commercial" and industrial areas, which share about 50% each of total electricity consumption. Electricity used in transport sector makes upon about 0.1% of the total electricity consumption.

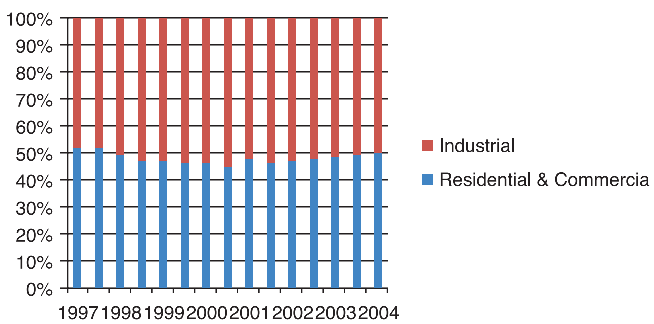


Figure 4.14 Shares of sectoral electricity demand in total electricity consumption (%)

g. Fuel shares in energy and electricity (per cent)

Crude oil remains the dominant conventional fossil fuel in energy supply, followed by natural gas. As shown in **Figure 4.15**, both of these fuels share a total of more than 85% of total energy supply. This indicates that Malaysia is highly dependent on petroleum. However, in line with the Eight Malaysia Plan (2001-2005) (EPU 2001), coal and coke as energy supply sources have increased. This, in turn indicates a reduction in dependency on the crude oil and natural gas.

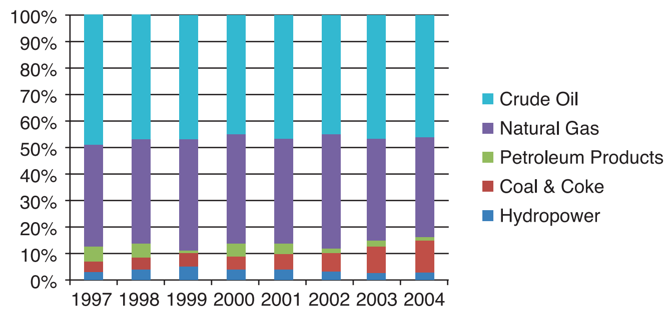


Figure 4.15 Fuel shares in total energy supply (%)

Figure 4.16 reveals that as of 2004, petroleum products remain the main energy consumed, though in line with the National Depletion Policy and Fuel Diversification Policy, the shares of petroleum products in total energy consumption have been declining.

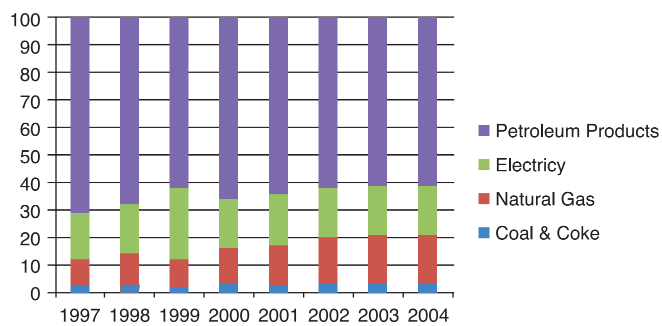


Figure 4.16 Fuel shares in total energy consumption (%)

Figure 4.17 shows that during the Seventh Malaysia Plan (1996-2000), the fuel mix for power generation has diversified through reduced dependency on fuel oil to increased use of natural gas and hydropower. Emphasis on diversification continued during the Eighth Malaysia Plan (2001-2005), as the share of both fuel oil and natural gas was reduced and the share of coal as electricity generating source increased. This, in turn demonstrates the success of both development policy and energy policy in diversifying the generation mix.

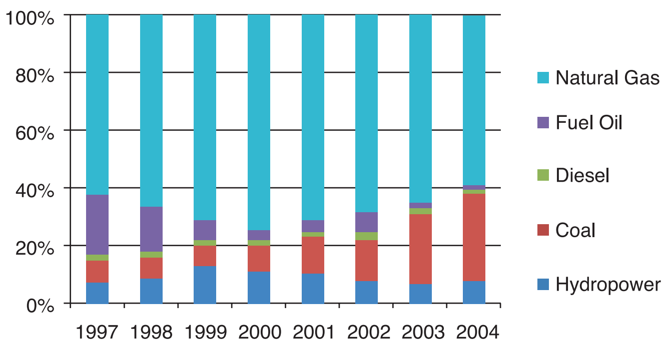


Figure 4.17 Fuel shares in electricity generation (%)

h. Capacity generated from RE and connected to the power supply grid

In line with the policy of promoting the utilisation of renewable energy sources, a total of 350 MW generated from RE was set as a target to be achieved by 2010 (EPU 2006). As of 2006, a total of 12 MW was generated from RE: 10 MW from empty fruit bunches and 2 MW from biogas. This accounts for only about 3.4% of the 2010 target.

i. End-use energy prices by fuel (RM)

Figure 4.18 providessome energy prices with and without subsidies in Malaysia. The energy prices shown in the figure are the average prices of Peninsular Malaysia, Sabah and Sarawak that have been adjusted since March 2006. The unsubsidised prices are far higher than the retail prices. The Government subsidises about half of the unsubsidized price of LPG, as a policy for promoting this clean cooking fuel.

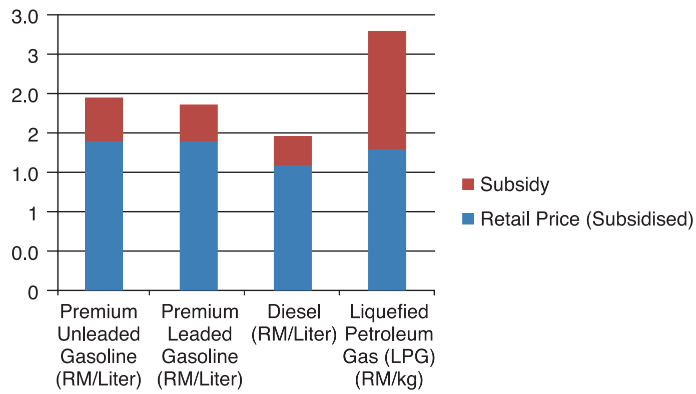


Figure 4.18 End-use energy prices with and without subsidies in Malaysian Ringgit

j. Reserves-to-production-ratio

Per **Figure 4.19**, the proven reserves of fuels especially natural gas, have declined tremendously since 1994. Hence, proper management of proven energy reserves is a crucial issue in the national sustainable energy programmes.

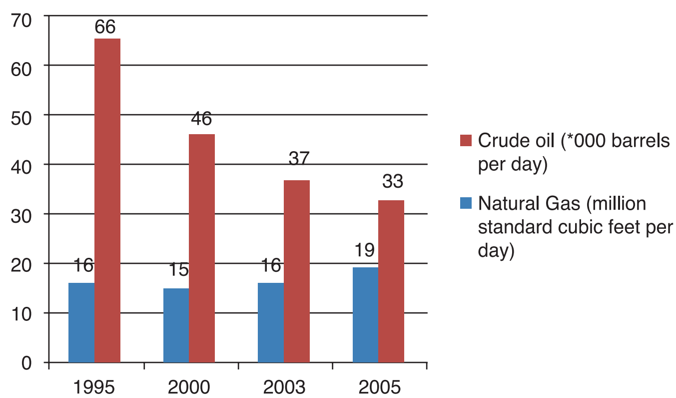


Figure 4.19 Reserves-to-production-ratio (Years)

k. GHG emissions from energy consumption per unit of GDP

Table 4.5 shows the latest available data of three main GHG emissions from energy consumption per GDP in 1994, 2000 and 2001. CO2 emission intensity (tonnes per RM million) increased at an average annual growth rate of 3.9% from 1994 to 2001 and appears to be linked to economic growth.

Table 4.5 GHG emissions from energy consumption per unit of GDP

Year	Tonnes of CO_2 equivalent/RM Million		
	CO_2	CH_4	N_20
1994	548.57	86.68	0.71
2000	637.78	Not available	Not available
2001	718.15	Not available	Not available

Data on CO_2 emissions from energy consumption of petroleum, natural gas, and coal and flaring of natural gas are available from the USA Energy Information Administration (EIA) energy statistics database. The total of CO_2 emissions from the consumption of the energy sources per dollar of GDP (carbon intensity) obtained from the USA EIA are as shown in **Figure 4.20**, for Malaysia and other selected countries. Malaysia's carbon intensity is about the same as that of the USA.

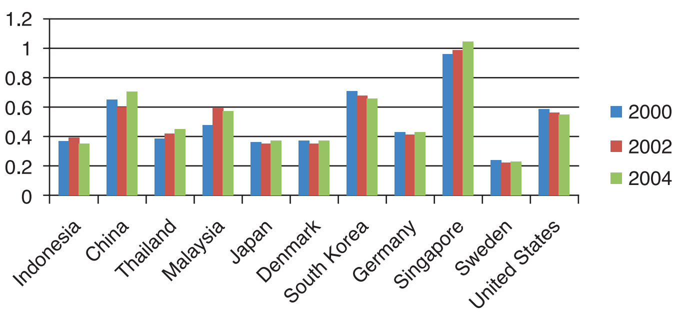


Figure 4.20 CO2 emissions from the energy consumption per dollar of GDP for a number of countries (Tonnes/'000 2000 USD)

I. Shares of emission loads from energy sector in air pollutant emissions (per cent)

Figure 4.21 shows that CO pollutant emissions are mainly from energy combustion activities, especially from transportation. The load of SO2 emissions from energy sector in 2005 increased almost 30% compared to 2003.

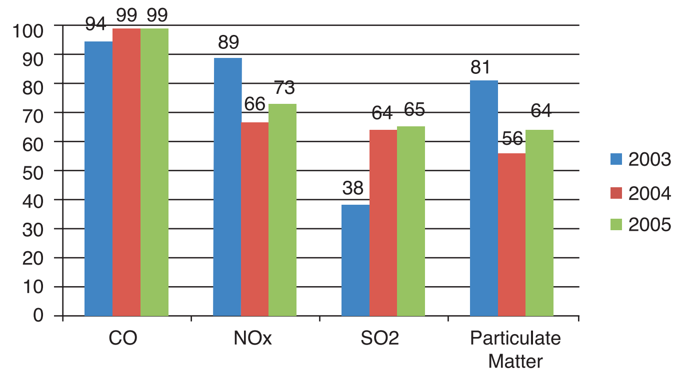


Figure 4.21 Shares of emission loads from energy sector in each type of air pollutant emissions (%).

Source: Chan Hoy Yen *et. al* 2008

4.6 CASE STUDY

4.6.1 CASE STUDY IN GERMANY

4.6.1.1 GENERATION SYSTEM

For various technical and economic reasons, the use of solid biofuels is seen in the southern part of Germany. The power plant fired with hard coal analysed here is characterised by an installed electric capacity of 509 MW and an efficiency of 43.2%. It is fired with pulverised hard coal from German underground hard coal mines. The full load of this plant is 5000 h/year and the technical lifetime is 30 years, as shown in **Figure 4.22**.

Germany plans to carry out a billion-dollar project that includes wind power generation and transmission over long transmission line. The project is to build 3800 kilometres (more than 2300 miles) of high-voltage lines — 2100 km direct current lines and 1700 alternating current lines — stretching from the coasts of the Baltic and North Seas toward the southern parts of the country. The government wants about 10 gigawatts of offshore wind installed by 2022 in order to help meet the country's renewable energy goals. By 2030, the hope is that more than 25 gigawatts will be installed - on the order of 5000 turbines, depending on size. In Germany, such output peaked at 22 gigawatts for a few hours on

Friday and Saturday, yielding almost half the country's energy needs from the renewable resource and setting a new record in the process.

In 2011, gross electric power generation in Germany totalled 615 billion kWh. A major proportion of the electricity supply is based on lignite (24.9%), hard coal (18.6%) and nuclear energy (17.6%). Natural gas has a share of 13.7%. Renewables (wind, water, biomass, photovoltaic) account for 19.9%.]

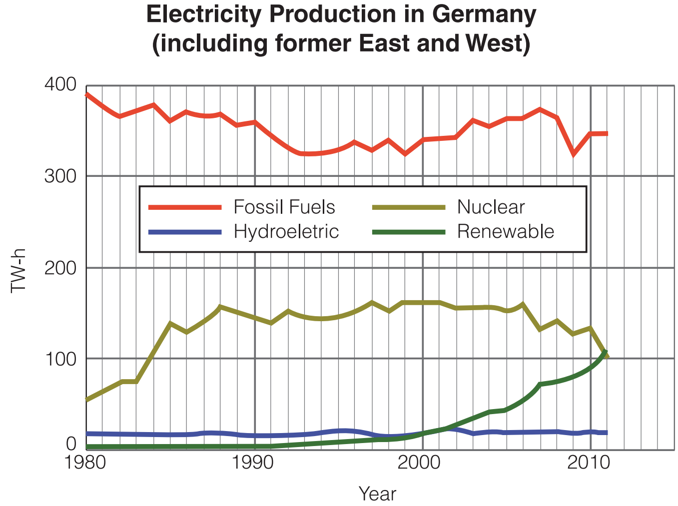


Figure 4.22 Electricity production in Germany

Nuclear Power: Nuclear power in Germany accounted for 17.7% of national electricity supply in 2011, compared to 22.4% in 2010. It has been high on the political agenda in recent decades, with continuing debates about when the technology should be phased out due to the political impact of the Russia-Belarus energy dispute and in 2011 after the Fukushima I nuclear accidents. On 30 May 2011, Germany formally announced plans to abandon nuclear energy completely within 11 years.

Renewable: Germany Renewable Energy share of gross electricity consumption rose from 10% in 2005 to 20% in 2011. Main renewable electricity sources were as follows in the first half of 2012: Wind energy 36.6%, biomass 22.5%, hydropower 14.7%, photovoltaics (solar) 21.2% and bio waste 3.6% as shown in **Figure 4.23**.

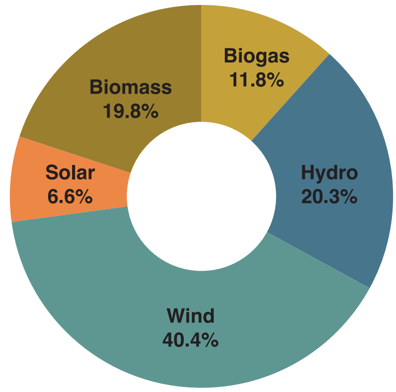


Figure 4.23 Germany Renewable electric power produced in 2009 by source

Germany's electricity transmission system is connected to neighbouring countries, and Germany participates in some cross-border electricity trade.

4.6.1.2 TRANSMISSION SYSTEM

Germany is going to build 3800km of high voltage line in which 2100 km HVDC line and 1700 km AC lines from the coasts of Baltic and North Seas towards the southern parts of the country. The new lines will cost around €20 billion (close to USD25 billion), and will require serious buy-in from the public and politicians alike to get the project done. Another transmission line is 58km overhead line from Miesbach to Munich. In Germany, about 1000 km of overhead line has been constructed.

4.6.1.3 DISTRIBUTION SYSTEM

Distribution systems carry lower voltages than transmission systems over networks of overhead lines, underground cables and substations. They take over the role of transporting electricity from the transmission network, and deliver it to consumers at a voltage they can use. The voltage rating and frequency for distribution system in Germany is 230 V and 50 Hz respectively. The socket outlet is type C&F also known as CEE7/16.

4.6.2 CASE STUDY IN UNITED STATES (US)

4.6.2.1 GENERATION SYSTEM

The electricity sector of the United States includes a large array of stakeholders that provide services through electricity generation, transmission, distribution, and marketing for industrial, commercial, public, and residential customers. In 2011, the total of installed electricity generation summer capacity in the United States was 1,050.9 GW. The main energy sources for electricity generation include:

- Thermal/Fossil 786 GW
- Nuclear 101 GW
- Hydropower 79 GW
- Wind 46 GW

Furthermore, the actual USA electricity generation in 2011 was4,100.7 Terawatt hours. The USA also imported 52 Terawatt hours and exported 15 Terawatt hours fora total of 4138.7 Terawatt hours for consumption. The electricity generation was primarily from the following sources:

- Thermal/Fossil 2789 TWh
- Nuclear 790 TWh
- Hydropower 319 TWh
- Other renewables 194 TWh (includinglandfill gas, geothermal energy, solar and wind)

About 75% of electricity sales to final customers are undertaken by private utilities, with the remainder being sold by municipal utilities and cooperatives.

Table 4.6 Electricity Generation of US in 2010

Net Generation	4,120.03 bn kW·h	100%
Total Conventional	2,880.68 bn kW·h	69.392%
Total Renewables	436.468 bn kW·h	10.59%
Total Nuclear	806.968 bn kW·h	19.59%

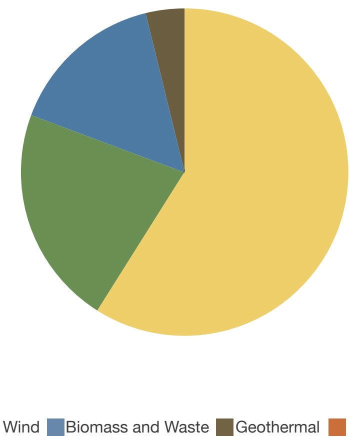


Figure 4.24 Electricity from renewable sources in US 2010

The US Energy Information Administration (EIA) estimated that in 2008, 10% of the world's energy consumption was from renewable energy sources. The EIA forecasts that by 2035, consumption of renewable energy will be about 14% of total world energy consumption.

4.6.2.2 TRANSMISSION SYSTEM

There are two major Alternating Current (AC) power grids in North America, the Eastern Interconnection and the Western Interconnection. Besides this, there are two minor power grids in the USA, the Alaska Interconnection and the Texas Interconnection. The Eastern, Western, and Texas Interconnections are tied together at various points with DC interconnects allowing electrical power to be transmitted throughout the contiguous US, Canada and parts of Mexico. The first HVDC system using a Modular Multi-Level Converter Supplier was installed in 2010 between Pittsburgh to San Francisco of USA with 85 km cable and 200 km overhead line for 400 MW power transmissions.

4.6.2.3 DISTRIBUTION SYSTEM

The distribution system in USA is much similar to European layout in terms of conductors, cables, insulators, surge arresters, regulators and transformers. This system is radial and voltage and power carrying capabilities are also similar to European layout. These typically deliver voltages as high as 34,000 volts (34 kV) and as low as 120 Volts. The distribution voltage rating is 120V and frequency is 60 Hz for residential customers.

The electrical outlet of USA is of type A&B — also known as NEMA 1-14. Most industries need 2,400 to 4,160 Volts to run heavy machinery and usually their own substation or substations to reduce the voltage from the transmission line to the desired level for distribution throughout the plant area. They usually require 3-phase lines to power 3-phase motors.

Commercial customers are usually served at distribution voltages, ranging from 14.4 kV to 7.2 kV through a service drop line, which leads from a transformer on or near the distribution pole to the customer's end use structure. Currently the only electric transportation systems are light rail and subway systems. A small distribution substation reduces the local distribution voltage to the transportation system requirements. The overhead lines supply electric power to the transportation system motors and the return current lines are connected to the train tracks.

4.7 GLOBAL PERSPECTIVE IN ELECTRICITY DEMAND GROWTH

4.7.1 GROWTH IN ELECTRICITY USE SLOWS DOWN BUT STILL INCREASES BY 28% FROM 2011 TO 2040

The growth of electricity demand (including retail sales and direct use) has slowed in each decade since the 1950s, from a 9.8-per cent annual rate of growth from 1949 to 1959 to only 0.7% per year in the first decade of the 21st century. In the (AEO 2013) referred to case, electricity demand growth remained relatively slow, as increasing demand for electricity services was offset by efficiency gains from new appliance standards and investments in energy-efficient equipment. The total of electricity demand increased by 28% in the projection (0.9% per year), from 3,839 billion kilowatt-hours in 2011 to 4,930 billion kilowatt-hours in 2040.

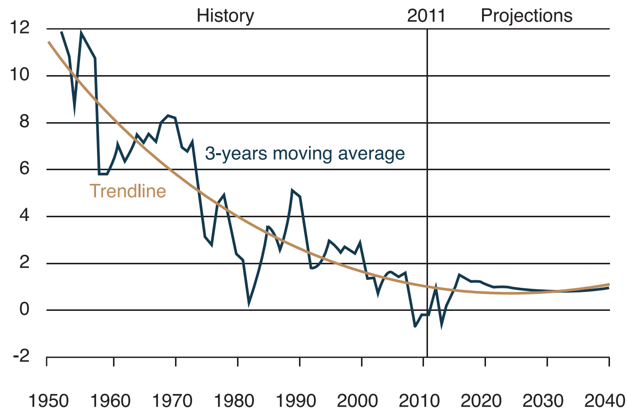


Figure 4.25 US Electricity demand growth, 1950 – 2040

The sales of retail electricity grew by 24% (0.7% per year) in the reference case, from 3,725 billion kilowatt-hours in 2011 to 4,608 billion kilowatt-hours in 2040. Residential electricity sales have also increased by 24%, to 1,767 billion kilowatt-hours in 2040, spurred by population growth and continued population shifts to warmer regions with greater cooling requirements. This is led by demand in the service industries, sales of electricity to the commercial sector increase by 27%, to 1,677 billion kilowatt-hours in 2040. Sales to the industrial sector grow by 17%, to 1,145 billion kilowatt-hours in 2040. Electricity sales to the transportation sector, although relatively small, triple from 6 billion kilowatt-hours in 2011 to 19 billion kilowatt-hours in 2040 with increasing sales of electric plug-in LDVs.

The demand for electricity can vary according to different assumptions on economic growth, electricity prices, and advances in energy-efficient technologies. In the High Economic Growth case, demand grows by 42% from 2011 to 2040, compared with 18% in the Low Economic Growth case, whereas 7% is in the Best Available Technology case. Average electricity prices (in 2011 dollars) increase by 5% from 2011 to 2040 in the Low Economic Growth case and 13% in the High Economic Growth case, to 10.4 and 11.2 cents per kilowatt-hour, respectively, in 2040 (EIA 2013).

4.7.2 COAL-FIRED PLANTS CONTINUE TO BE THE LARGEST SOURCE OF US ELECTRICITY GENERATION

Coal-fired power plants continue to be the largest source of electricity generation in the (AEO 2013), reference case. However, their market share has declined significantly. From 42% in 2011, coal's share of total US generation will decline to 38% in 2025, and 35% in 2040. Approximately 15% of the coal-fired capacity active in 2011 is expected to be retired by 2040 in the reference case, while only 4% of new generating capacity added has been coal-fired. Existing coal-fired units that have undergone environmental equipment retrofits continue to operate throughout the projection.

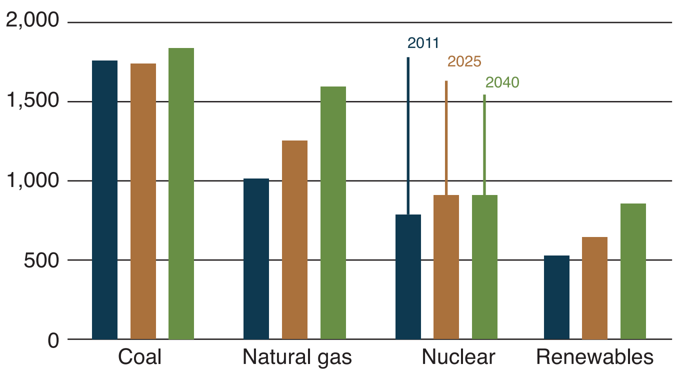


Figure 4.26 Electricity generation by fuel, 2011, 2025 and 2040 (billion kilowatt-hours)

The generation from natural gas increases by an average of 1.6% per year from 2011 to 2040, and its share of total generation grows from 24% in 2011 to 27% in 2025, and 30% in 2040. The relatively low cost of natural gas makes the dispatching of existing natural gas plants more competitive with coal plants and, in combination with relatively low capital costs, makes plants fuelled by natural gas an alternative choice for new generation capacity.

In contrast, the generation from renewable sources grew by 1.7% per year on average in the reference case, and the share of total generation will increase from 13% in 2011 to 16% in 2040. Meanwhile, the non-hydropower share of total renewable generation increases from 38% in 2011 to 65% in 2040. Thus, generation from US nuclear power plants increases by 0.5% per year on average from 2011 to 2040, with most of the growth between 2011 and 2025, Nevertheless, the share of total US electricity generation will decline from 19% in 2011 to 17% in 2040, as the growth in nuclear generation will be outpaced by growth in generation using natural gas and renewables (EIA 2013).

4.7.3 MOST NEW CAPACITY ADDITIONS USE NATURAL GAS AND RENEWABLES

Decisions to add capacity, and the choice of fuel for new capacity, depend on a number of factors. With growing electricity demand and the retirement of 103 gigawatts of existing capacity, 340 gigawatts of new generating capacity was added in the (AEO 2013), reference case from 2012 to 2040.

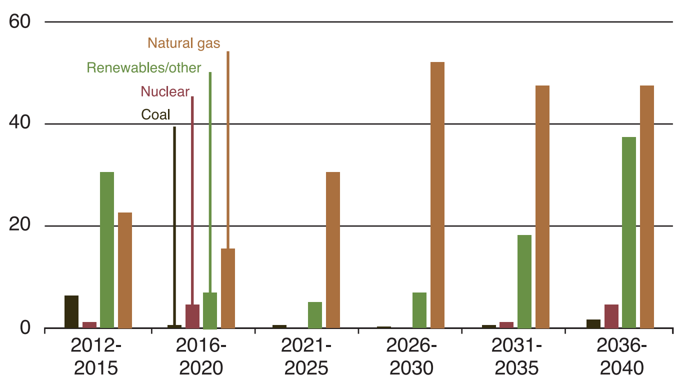


Figure 4.27 Electricity generation capacity additions by fuel type, Including combined heat and power, 2012-2040 (GW)

Natural gas-fired plants account for 63% of capacity additions from 2012 to 2040 in the reference case, as compared to 31% for renewables, 3% for coal, and 3%

for nuclear. The escalating construction costs have the largest impact on capital-intensive technologies, which include nuclear, coal, and renewables. Nevertheless, Federal tax incentives, State energy programmes, and rising prices for fossil fuels increase the competitiveness of renewable and nuclear capacity. The current Federal and State environmental regulations also affect the use of fossil fuels, particularly coal. The uncertainty over the future limits on GHG emissions and other possible environmental programmes also reduces the competitiveness of coal-fired plants (reflected in the (AEO 2013) reference case by adding 3 percentage points to the cost of capital for new coal-fired capacity).

The uncertainty over electricity demand growth and fuel prices also affects capacity planning. Total capacity additions from 2012 to 2040 range from 252 gigawatts in the Low Economic Growth case to 498 gigawatts in the High Economic Growth case. In the Low Oil and Gas Resource case, natural gas prices are higher than in the reference case, and new natural gas-fired capacity added from 2012 to 2040 totals 152 gigawatts, or 42% of total additions. In the High Oil and Gas Resource case, delivered natural gas prices are lower than in the reference case, and 311 gigawatts of new natural gas-fired capacity is added from 2012 to 2040, accounting for 82% of total new capacity (EIA 2013).

4.7.4 ADDITIONS TO POWER PLANT CAPACITY SLOW AFTER 2012 BUT ACCELERATE BEYOND 2023

Typically, investments in electricity generation capacity have gone through boom-and-bust cycles. Periods of slower growth have been followed by strong growth in response to changing expectations for future electricity demand and fuel prices, as well as changes in the industry, such as restructuring. A construction boom in the early 2000s saw capacity additions averaging 35 gigawatts a year from 2000 to 2004. Since then, average annual builds have dropped to 18 gigawatts per year from 2006 to 2011.

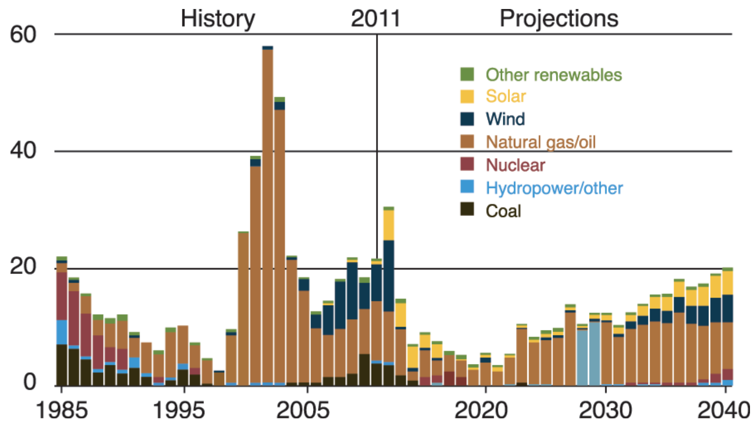


Figure 4.28 Additions to electricity generating capacity 1985-2040 (GW)

To illustrate, in the (AEO 2013) reference case, capacity additions from 2012 to 2040 will come to a total of 340 gigawatts, including new plants built not only in the power sector but also by end-use generators. Annual additions in 2012 and 2013 remain relatively high, averaging 22 gigawatts per year. Of those early builds, 51% are renewable plants built to take advantage of Federal tax incentives and to meet State renewable standards.

Annual builds drop significantly after 2013 and remain below 9 gigawatts per year until 2023. During that period, existing capacity is adequate to meet growth in demand in most regions, given the earlier construction boom and relatively slow growth in electricity demand after the economic recession. Between 2025 and 2040, average annual builds increase to 14 gigawatts per year, as excess capacity is depleted and the rate of total capacity growth is more consistent with electricity demand growth. About 68% of the capacity additions from 2025 to 2040 are natural gas-fired, given that the higher construction costs for other capacity types and uncertainty about the prospects for future limits on GHG emissions (EIA 2013).

4.7.5 ADDITIONS TO POWER PLANT CAPACITY SLOW AFTER 2012 BUT ACCELERATE BEYOND 2023

Over the long term, growth in electricity generating capacity parallels the growth in end-use demand for electricity. Unexpected shifts in demand or dramatic changes affecting capacity investment decisions may, however, cause imbalances that can take years to be worked out.

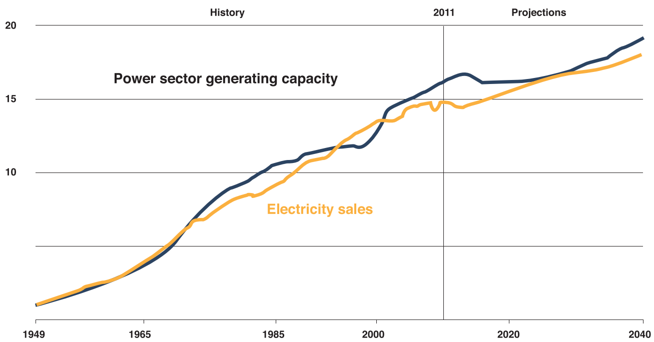


Figure 4.29 Electricity sales and power sector generating capacity, 1949 – 2040 (indexes, 1949=1.0)

Figure 4.28 indicates indexes summarising relative changes in total generating capacity and electricity demand. During the 1950s and 1960s, the capacity and demand indexes tracked closely. The energy crises of the 1970s and 1980s, together with other factors, slowed electricity demand growth, and capacity growth outpaced demand for more than 10 years thereafter, as planned units continued to come online. Demand and capacity did not align again until the mid-1990s. Then, in the late 1990s, uncertainty about deregulation of the electricity industry caused a downturn in capacity expansion, and another period of imbalance followed, with growth in electricity demand exceeding capacity growth.

In 2000, a boom in construction of new natural gas-fired plants began, bringing capacity back into balance with demand and creating excess capacity. Construction of new wind capacity that sometimes needs backup capacity because of intermittency also began to grow after 2000. More recently, the 2007-2009 economic recessions caused a significant drop in electricity demand, which has yet to recover. Slow near-term growth in electricity demand in the (AEO 2013) reference case creates excess generating capacity. Thus, although the capacity currently under construction is completed, but a limited amount of additional capacity is built before 2025, while older capacity is retired. By 2025, capacity growth and demand growth are in balance again, and they grow at similar rates through 2034. In the later years, the total capacity escalates at a rate slightly higher than demand, due in part to an increasing share of intermittent renewable capacity that does not contribute to meeting demand in the same proportion as dispatchable capacity.

4.7.6 COSTS AND REGULATORY UNCERTAINTIES VARY ACROSS OPTIONS FOR NEW CAPACITY

Technology choices for new generating capacity are based largely on capital, operating, and transmission costs. Coal, nuclear, and wind plants are capital-intensive, whereas operating (fuel) expenditures make up most of the costs for natural gas plants. Capital costs depend on such factors as equipment costs, interest rates, and cost recovery periods, which vary with technology. Fuel costs vary with operating efficiency, fuel price, and transportation costs.

In addition to considerations of levelised costs, some technologies and fuels receive subsidies, such as production or ITCs. The new plants must also fulfil local and Federal emission standards, ensuring compatibility with the utility's load profile.

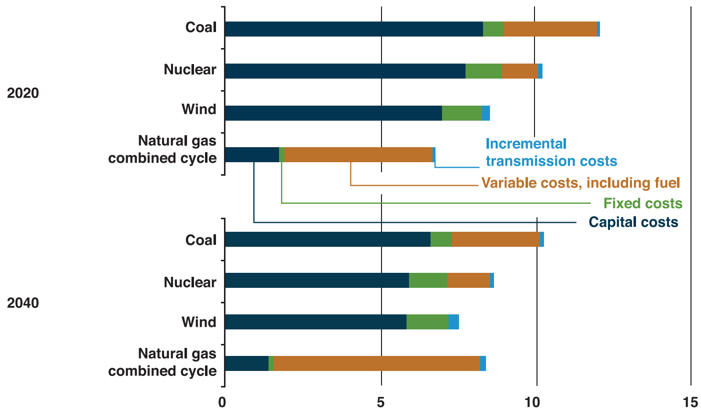


Figure 4.30 Levelised electricity costs for new power plants, excluding subsidies, 2020 and 2040(2011 cents per KW)

The regulatory uncertainty also affects capacity planning. New coal plants may require carbon control and sequestration equipment, resulting in higher material, labour, and operating costs. Alternatively, coal plants without carbon controls could incur higher costs for siting and permitting. As nuclear and renewable power plants (including wind plants) do not emit GHGs, their costs are not directly affected by regulatory uncertainty in this area.

The capital costs can decline over time as developers gain technology experience, with the largest rate of decline observed in new technologies. In the (AEO 2013) reference case, the capital costs of new technologies are adjusted upward initially to compensate for the optimism inherent in early estimates of project costs, which then decline as project developers gain experience. The decline continues at a progressively slower rate as more units are built. Operating efficiencies also are assumed to improve over time, resulting in reduced variable costs unless increases in fuel costs exceed the savings from efficiency gains.

4.7.7 NUCLEAR POWER PLANT CAPACITY GROWS SLOWLY THROUGH UP RATES AND NEW BU

In the (AEO 2013) reference case, nuclear power capacity increases from 101.1 gigawatts in 2011 to a peak of 114.1 gigawatts in 2025, before declining to 108.5 gigawatts in 2036, largely as a result of plant retirements. New additions in the later years of the projection bring nuclear capacity back up to 113.1 gigawatts in 2040. The capacity increase through 2025 includes 8.0 gigawatts of expansion at existing plants and 4.5 gigawatts of new capacity, which includes completion of a conventional reactor at the Watts Bar site.

Namely, four advanced reactors, reported as under construction, also are assumed to be brought online by 2020 and to be eligible for Federal financial incentives. High construction costs for nuclear plants, especially relative to natural gas-fired plants, make additional options for new nuclear capacity uneconomical until the later years of the projection, when an additional 4.5 gigawatts is added. Nuclear capacity additions vary with assumptions about overall demand for electricity. Across the Economic Growth cases, net additions of nuclear capacity from 2012 to 2040 range from 4.5 gigawatts in the Low Economic Growth case to 36.1 gigawatts in the High Economic Growth case.

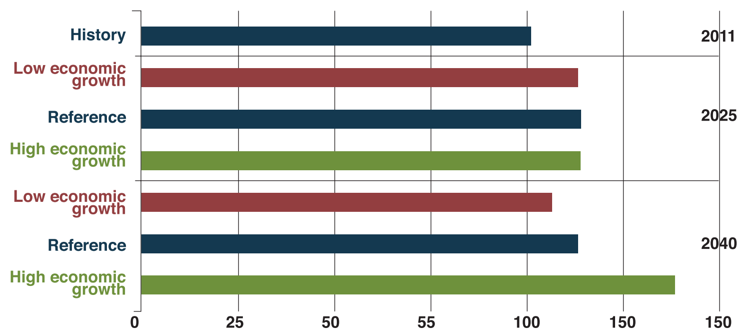


Figure 4.31 Electricity generating capacity at US nuclear power plants in three cases, 2011, 2025 and 2040 (GW)

One nuclear unit, the Oyster Creek, is expected to be retired at the end of 2019, as announced by Exelon in December 2010. An additional 6.5 gigawatts of nuclear capacity is assumed to be retired by 2036 in the reference case. All other existing nuclear units continue to operate through 2040 in the reference case, which assumes that they will apply for and receive operating license renewals, including in some cases a second 20-year extension after 60 years of operation (for more discussion, see 'Issues in focus'). With costs for natural gas-fired generation rising in the reference case and uncertainty about future regulation of GHG emissions, the economics of keeping existing nuclear power plants in operation are favourable.

4.7.8 SOLAR PHOTOVOLTAICS AND WIND DOMINATE RENEWABLE CAPACITY GROWTH

Renewable generating capacity accounts for nearly one-fifth of total generating capacity in 2040 in the (AEO 2013) reference case. Nearly all renewable capacity additions over the period consist of non-hydropower capacity, which grows by more than 150% from 2011 to 2040.

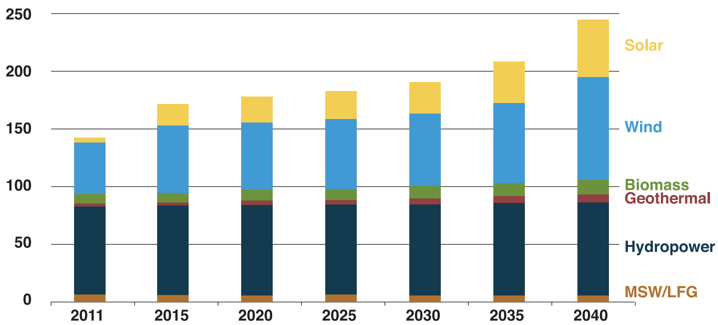


Figure 4.32 Renewable electricity generation capacity by energy source, including end-use capacity, 2011-2040 (GW)

Solar generation capacity leads to renewable capacity growth, increasing by more than 1,000%, or 46 gigawatts, from 2011 to 2040. Wind capacity follows closely, accounting for an additional 42 gigawatts of new renewable capacity by 2040. Nonetheless, wind continues to be the leading source of non-hydropower renewable capacity in 2040, given its relatively high initial capacity in 2011, after a decade of exponential growth resulting from the availability of production tax credits and other incentives. Although geothermal and dedicated biomass generation capacity do not increase on the same scale as wind and solar (contributing an additional 5 gigawatts and 7 gigawatts, respectively, over the projection period), biomass capacity nearly doubles and geothermal capacity more than triples over the same period.

Renewable capacity additions are supported by State RPS, the Federal renewable fuel standard, and Federal tax credits. Near-term growth is strong as developers build capacity to qualify for tax credits that expire at the end of 2012, 2013, and 2016. After 2016, capacity growth through 2030 is minimal, given relatively slower growth in electricity demand, low natural gas prices, and the stagnation or expiration of the State and Federal policies that support renewable capacity additions. As the need for new generation capacity increases, however, and as renewables become increasingly cost-competitive in selected regions, growth in non-hydropower renewable generation capacity rebounds during the final decade of the reference case projection from 2030 to 2040.

4.7.9 SOLAR, WIND, AND BIOMASS LEAD GROWTH IN RENEWABLE GENERATION, HYDROPOWERREMAINS FLAT

In the (AEO 2013) reference case, renewable generation increases from 524 billion kilowatt-hours in 2011 to 858 billion kilowatt-hours in 2040, growing by an average of 1.7% per year. Wind, solar, and biomass account for most of the growth. The increase in wind-powered generation from 2011 to 2040, at 134 billion kilowatt-hours, or 2.6% per year, represents the largest absolute increase in renewable generation. Generation from solar energy grows by 92 billion kilowatt-hours over the same period, representing the highest annual average growth at 9.8% per year. Biomass increases by 95 billion kilowatt-hours over the projection period, for an average annual increase of 4.5%.

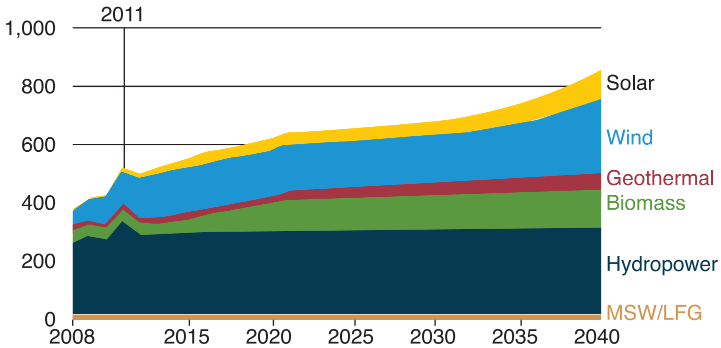


Figure 4.33 Renewable electricity generation by type including end-use generation, 2008-2040 (BKW)

Hydropower production dropped in 2012 from 325 billion kilowatt-hours in 2011, as existing plants are assumed to continue operating at their long-term average production levels. Even with little growth in capacity, hydropower remains the leading source of renewable generation throughout the projection. Although the total wind capacity exceeds hydropower capacity in 2040, wind generators typically operate at much lower capacity factors, and their total generation is lower. Biomass is the third-largest source of renewable generation throughout the projection, with rapid growth particularly in the first decade of the period, reaching 102 billion kilowatt-hours in 2021 from 37 billion kilowatt-hours in 2011. The strong growth is a result primarily of increased penetration of co-firing technology in the electric power sector, encouraged by state-level policies and increasing cost-competitiveness with coal in parts of the Southeast.

4.8 ENERGY SECURITIES

4.8.1 NUCLEAR POWER PROGRAMME IN MALAYSIA

The Malaysian Government has yet to decide on the implementation of the construction of nuclear power plant in Malaysia. Current activities focus on detailed studies to identify issues and considerations as well as to objectively determine and assess the current level of national capabilities and State-of-preparedness pertaining to the development of a national nuclear power programme, as one of the 131 Entry Point Projects (EPP) under Malaysia Economic Transformation Programme (ETP). Pre-Project Activities are spearheaded by Malaysia Nuclear Power Corporation (MNPC), as NEPIO and Nuclear Malaysia as TSO with a tentative nuclear timeline. The actual decision to implement nuclear power projects, however, will be guided by the Government's decision, after taking into account the recommendations in the details studies.

4.8.2 WHY NUCLEAR DESPITE HIGH RESERVE MARGIN?

One of commonly raised question is why does Peninsular Malaysia still need to install nuclear plants despite having high reserve margin. At present, the peak demand stands at 15,072 MW, as recorded on 25 May 2010. This translates into reserve margin of approximately 40%. The reserve level is not here to stay. With annual load growth and retirement of existing capacity as they reach their economic life, the reserve margin will eventually drop.

The demand for electricity in Peninsular Malaysia is expected to surge at 3-5% annually from 2010 until 2020. In 2020, peak demand is forecasted at 20,669 MW while energy generation is projected to reach 138,510 GWh. In Peninsular Malaysia, there is no new plant scheduled for installation from now until 2014. Hence, with no added capacity from new plants, higher electricity demand and retirements of older plants, reserve margin is expected to reduce. In 2015, it will settle at approximately 20%. The figure below shows the decreasing trend of reserve margin due to increasing demand forecast (assuming no new load is introduced to the system).

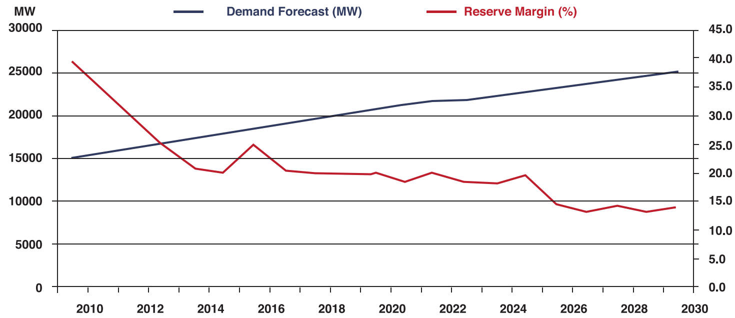


Figure 4.34 Demand forecast and reserve margin curve (TNB 2013)

4.8.3 ENERGY FOR FUTURE

Nuclear plants are necessary for electricity generation in Peninsular Malaysia, as it will add diversification to the generation mix. At present, Peninsular Malaysia relies heavily on gas. In FY08/09 alone, 65% of electricity generation came from gas. This is followed by coal at 29%, and 6% from hydro.

Going forward, most of Malaysia's fuel sources will be imported, including gas. Fossil fuel will be replenished on real time basis. Any disruption on the supply side could pose major risk in failing to meet demand. Namely, Nuclear power generation is different from other technologies. Fuel is loaded once in an 18-24 month cycle. The long fuel cycle allows for better planning and less exposure on supply security risks. Hence, security of supply is guaranteed.

Apart from that, natural gas for the future could become an import fuel. PETRONAS has indicated that the local gas fields are depleting. Currently, the source of natural gas comes from domestic fields as well as export from Joint Development Area (JDA) and from West Natuna.The production from all these sources has been decreasing, as shown in graph below.Thus, this scenario indicates that Peninsular Malaysia can no longer heavily rely on gas for electricity generation in the future due to its rapid depletion.

At present, coal for electricity generation is fully imported from other countries, which include Indonesia, Australia and South Africa. Among the major issues concerning governing coal is the risk of supply. Therefore, coal exporting countries could change their policy in the future if they see a need to utilise more for their own local consumption.

Likewise,there is stiff competition from China and India for coal as these countries are undergoing rapid development. We are also competing with Korea, Japan and Taiwan for coal. This situation definitely exerts tremendous pressure on the price. Logistic and politics are other issues arising from electricity generation from coal. Coal is transported via ships to the jetty and finally stored at the coal yard inside the plant site. Problem could arise due to bad weather or labour strikes, as this will cause the disruption of coal supply.Consequently, these situations expose the country to higher risks of energy security if we become too dependent on one single source (TNB 2013).

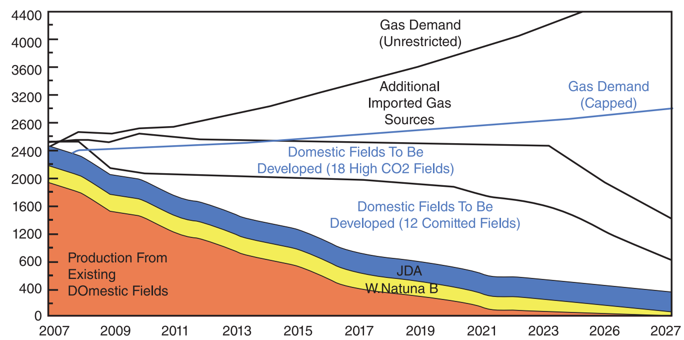


Figure 4.35 Availability of various sources

4.8.4 DO WE HAVE OTHER OPTIONS?

Hydro potential in Peninsular Malaysia is limited. Current remaining untapped hydropower stands at approximately only 1700 MW. This amount is relatively small to serve increasingly high electricity demand. In addition, the remaining potential in the Peninsular are mainly peaking-type, with limited energy. Another issue that revolves around hydro plants is relocation of people at the affected sites, which is normally complicated and may involve high costs.

With the introduction of the 5-Fuel Policy, RE is recognised as one of the main fuel for power generation. As of now, RE has been developed in Peninsular Malaysia via SREP. It has been established through willing buyer and willing seller basis between TNB and the SREP developers via Renewable Energy Power Purchase Agreement (REPPA). The table below shows the current status of RE through REPPA.

To date, a total of 59 applications were received. However, only 29% advanced with REPPA, for a total capacity of 88.15 MW. Now, there are only 6 plants in operation mode with a total capacity of only 24.7 MW. This figure shows that renewable energy has not been progressively developed. The slow uptake for renewable energy could be attributed to lack of robust commercial mechanism to support RE development.

Nevertheless, the Feed in Tariff was introduced by the Government in 2012, under the RE Act and Action Plan. Feed in Tariff entails purchasing power from RE developers at premium price. With the introduction of this mechanism, the development of RE is expected to increase. Nevertheless, Malaysia still needs to consider nuclear power due to several reasons, namely intermittency of RE, cost of technology, and the remote location of some of the RE sources. Development of RE should continue and hopefully with future technology advancement, more contribution from RE could be expected. However, this advancement might not be available in the near future. Hence, Malaysia has to look at readily available options such as nuclear power.

4.8.5 NUCLEAR VS. RENEWABLE ENERGY

Nuclear power development is not carried out to ostracize the development of RE. Previously in the Ninth Malaysian Plan (2006-2010), RE was set to achieve 300 MW by 2010. RE development is carried out through Small Renewable Energy Programme (SREP), as highlighted in the previous article. However the target was not achieved due to poor implementation. Nevertheless, Malaysia is highly committed to developing renewable energy as an RE Act, and the Malaysian government in 2012 rolled out an Action Plan. This new initiative is expected to help grow the RE development further.

Therefore, it is imperative to state that apple-to-apple comparison between nuclear plants and RE plants is not a fair practice. Energy generated from inexhaustible sources like solar, wind and biomass does not function in a similar manner to energy generated from nuclear plants. Nuclear plants are designed to generate power continuously at constant output and would normally run at capacity factor of 80% or higher. Unlike other plants, output from nuclear plants is not adjusted corresponding to daily demand due to sophisticated component designs.

Nuclear plants will be shut down only during fuel loading. The fuel loading for PWR type reactors is done once in every 15-18 months for about a month. Until the next fuel loading, these nuclear plants would be running at full operation. During fuel loading, fuel refilling and major inspections on plant components are carried out. Given these characteristics, nuclear plants are suitable for serving the base load requirements in Peninsular Malaysia. Currently, minimum demand stands at approximately 10,000 MW. As shown in the figure below, this minimum demand has to be completed by base load plants, which include coal and gas. Nuclear plants will add to list of plants operating as base load.

This base load requirement would not be met by RE utilisation as challenges remain in low capacity production. Going worldwide, typical solar PV stations have capacities ranging from 10-60 MW with the biggest solar PV plant installed in Spain (60 MW). Conversely, typical nuclear plants provide capacity between 600-1000 MW per unit.

This huge disparity of capacity makes RE unpalatable to work similarly as nuclear plants in providing the base load requirements. RE is done in small scale and thus can only supplement to supplying the demand. Relying on RE alone is impossible. Furthermore, there are other caveats with relying on RE alone. Namely, solar and wind power is subject to intermittency.

For that matter, the Peninsular Malaysia is blessed with sunlight as it sits on equatorial region with an average radiation of 4,500 kWh/m2. Malaysia receives four to six hours of sunshine every day. Based on these facts, solar PV development has a bright future. Nonetheless, besides highly capital intensive, another major drawback of solar power is requirement of vast area to produce reasonable amount of electricity. **Table 9** below shows the comparison of area needed to produce 1000 MWe between various sources.

Table 4.7 Comparison of area needed to produce 1000 MWe between various sources

Plants	Fuel for 1,000 MWe for 1 year
Solar	100 km^2 land area
Wind	3,000 Wind turbine of 1 MWe
Biogas	800 million chicken
Biomass	30,000 km^2 of plantation area

With regards to wind power in Peninsular Malaysia, there is limitation to untapped wind potentials. Several studies and research are have been conducted by various parties on the viability of harnessing wind energy in several regions located in Peninsular Malaysia. It has been concluded that wind potentials are low in Peninsular Malaysia. In addition, wind energy also suffers intermittency, which requires electrical compensation and storage. **Figure 4.36** below shows the map of wind speed and potentials in South East Asia.

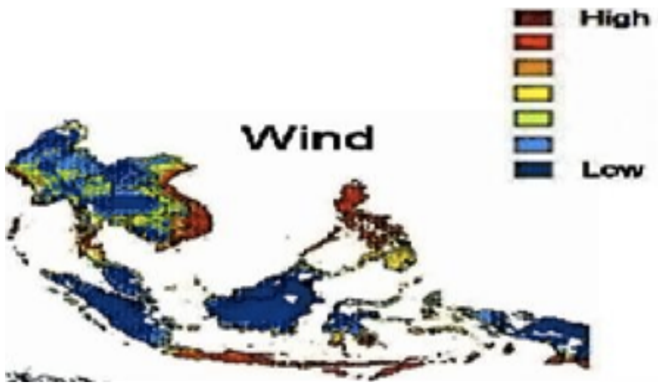


Figure 4.36 Wind flow overview in Malaysia region

Biomass, solid waste and biogas plants are among other RE sources that are rigorously being developed. To date, a total of 88 MW of RE projects were signed under SREP. From this figure, 40.35 MW comes from biomass and biogas plants. Unlike solar PV and wind, these sources do not face intermittency problem. It can generate electricity at any time since combustion of fuels is needed to produce electricity. However, the challenge remains with possible competition with other industry, which uses the same input sources. Furthermore, these sources are not completely clean technology, since burning of input sources is required to generate electricity.

Another great barrier suffocating RE development is high capital costs. Nevertheless, this may be addressed via Feed-in-Tariff (FiT) mechanism that will be launched in conjunction with RE Act and Action Plan in 2012. FiT are legally guaranteed payments for electricity produced by green energies such as solar, wind, biomass or small hydro power plants that is being fed into the national electricity grid. Through FiT, in which the concept of willing buyer and willing seller is established between developers and the utility company, the energy produced will be purchased at a premium price. This mechanism has been drafted and utilised in countries such as Germany, Spain, and the USA and it has successfully proven in increasing the growth of renewable energy.

To conclude, in comparison with RE, a nuclear plant is necessary to come on stream in order to serve the base load requirements due to its constant output production. RE does not provide security of supply. However, its development is without a doubt vital in providing clean energy in order to combat climate change and global warming as well as for fuel diversification purposes (TNB 2013).

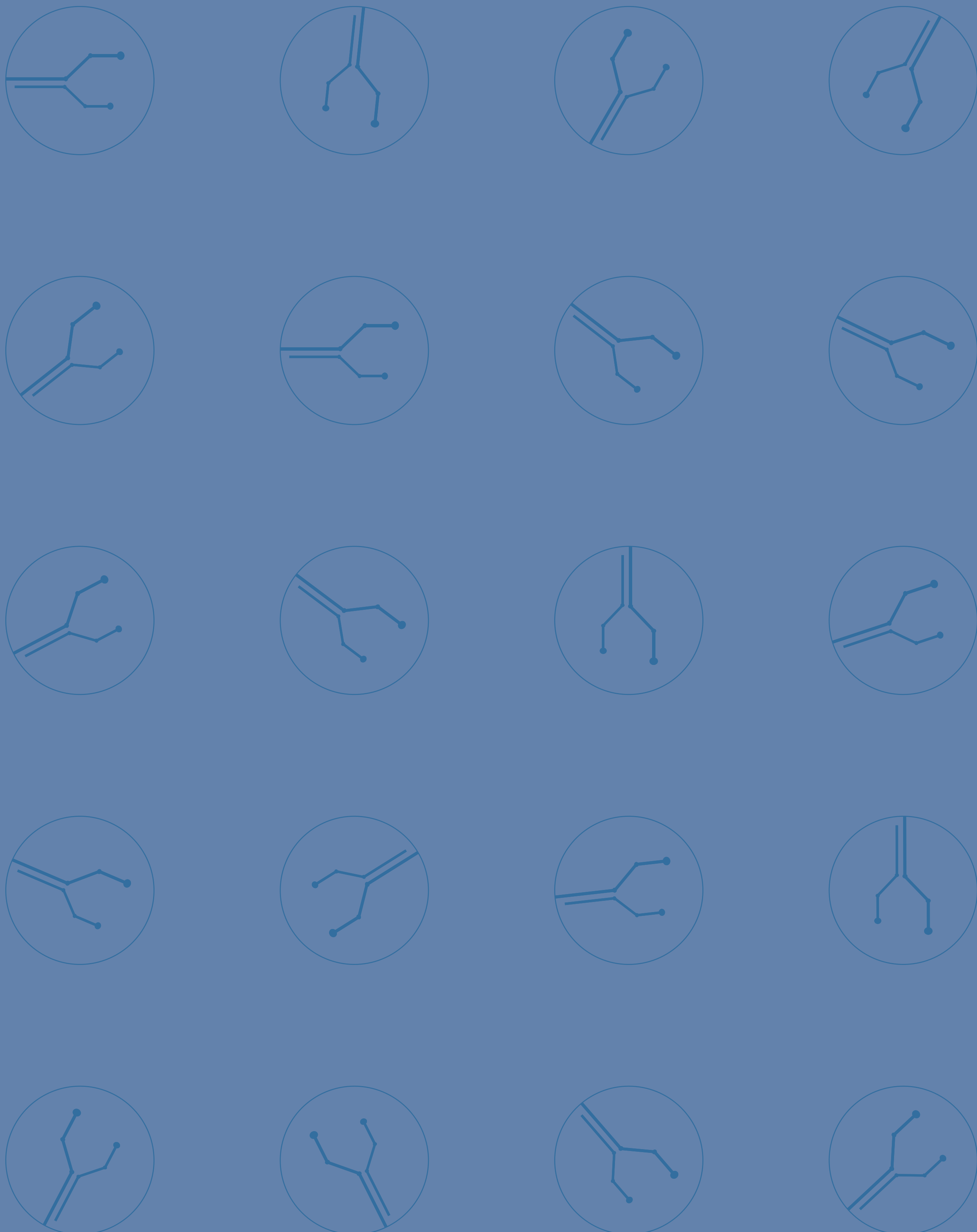
4.9 CONCLUSION

As examples are studied and followed, some countries have managed to used significant amount of RE for generation and consumption, such as Germany and Denmark. This sustainability assures economic and environmental benefits, reflecting on society by technology investment that result in job creation, employee's expansion and on environment by reduction in carbon dioxide emissions level, and complying with the Kyoto agreement.

Nevertheless, Malaysia's extreme dependence on exporting oil and natural gas to maintain its economic growth will stand longer if it switches to sustainable resources as soon as possible. At the moment, the Malaysian government has a dilemma: to inject millions either to green technology or to the nuclear plant plans? Electrification can be developed either way. Nuclear sources are environmentally friendly when under control, but when out of control is extremely dangerous for both humans and environment. Witness what happened in Fukushima Daiichi in Japan when the reactor went out of control. This will lead a wide rejection from the public special in area around the reactor.

Thus, in the near future, Malaysia needs to increase its power to cover the country's fast growth. In our humble vision, utilising smart grids could be the key aspect. Smart or Micro grids can be future backbone of electricity generation and storage, by exploiting different energy resources and storage. Like accompanied Head and Power (CHP), Electrical Vehicle batteries (Sitthidet & Issarachai 2012) these will be greatly effective in Malaysia working separated from the main grid, and can be supply to the grid when it is necessary.

Therefore, in observing the literature, it is evident that Malaysia has to launch certain distributed generation resources to avoid future increasing demand and or natural disasters. Meanwhile, we must avoid future disasters such as what happened in Japan, USA and Australia, which have caused a blackout of main electricity for weeks in some areas.



CHAPTER 5

ENERGY GENERATION, TRANSMISSION AND DISTRIBUTION - MOVING UP THE TECHNOLOGY VALUE CHAIN:CONCEPTUAL FRAMEWORK, GENERATION, TRANSMISSION, DISTRIBUTION, MALAYSIA'S STANDING

The Malaysian National Energy Policies comprise of the following:

- 1981 four-fuel diversification policy on oil, hydro, natural gas, as well as coal; and
- 2000 five-fuel diversification policy on oil, hydro, natural gas, coal, and 5% renewable energy.

Malaysia's electricity demands from 2008 to 2030 are forecasted as in **Figure 5.1**. Electricity demands from industry, commercial and residential areas are increasing steadily and the gap is growing wider.

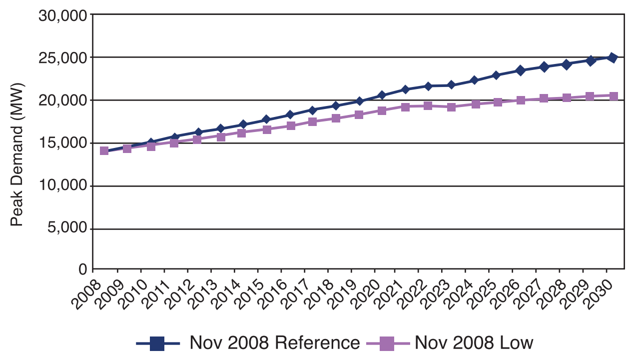


Figure 5.1 Malaysia electricity demands

There are only three major energy sources, despite the Five-Fuel Diversification Policy, with coal mostly imported, indigenous gas supply uncertain in long-term, and hydropower mostly in Sarawak. These sources may be adequate to only around 2030, as illustrated in **Figure 5.2**.

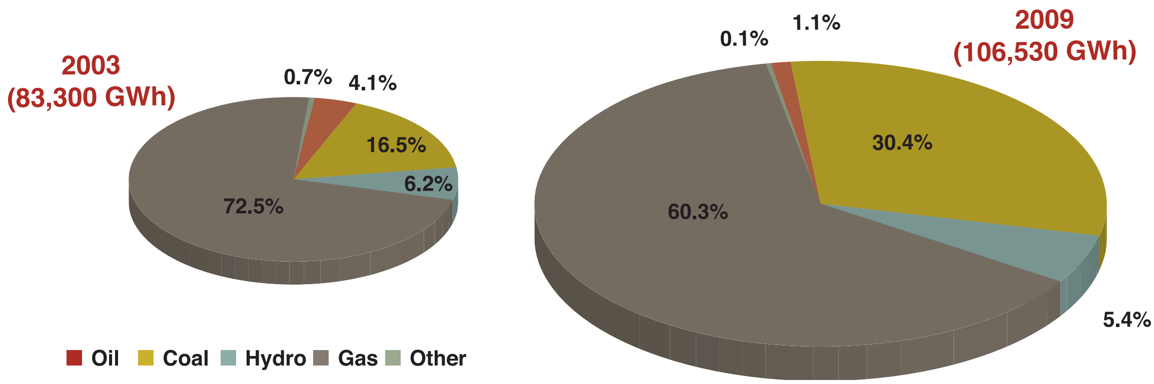


Figure 5.2 National power generation fuel mix

Note: The fuel issues are summarised in Table 5.1 below

Table 5.1 Fuel issues

No	Existing Fuel	Issues
1	Oil	Net importer by 2014, price fluctuation
2	Gas	Gas field depleted by 2027, Net importer by 2019
3	Coal	100% imported, price fluctuation, dwindling and security of supply
4	Hydro	Supply-demand geographical mismatch
5	Renewable	Small, decentralised, economic of scale, best serving peak load

Note: The demand and supply gap issue is shown in **Figure 5.3**

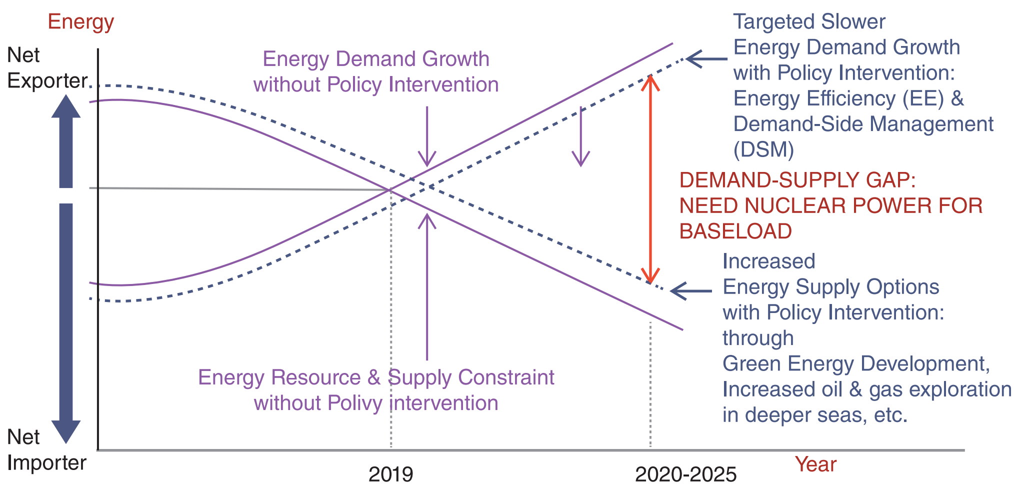


Figure 5.3 Demand-supply gaps

Source: EPU 2009

An energy requirement analysis is conducted based on increasing demand, lack of competitive, sustainable, commercial energy resources beyond 2020 for Malaysia, dwindling and uncertain supplies, and environmental considerations. Renewable energy is unable to fill in the gap adequately and is not appropriate for base load. Nuclear power is seen as a candidate for baseload energy source (Mohamad 2010).

5.1 FUTURE FOR NUCLEAR IN MALAYSIA

Comparative power generation economics are shown in **Figures 5.4**, **5.5**, and **5.5**. **Figure 5.4** shows the investment costs for a 1,000 MWe plant.

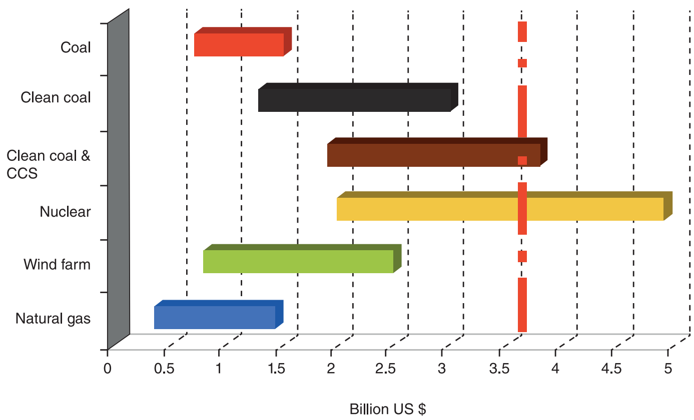


Figure 5.4 Investment costs for 1,000 MWe plant

Figure 5.5 shows the comparative cost structure by fuel type.

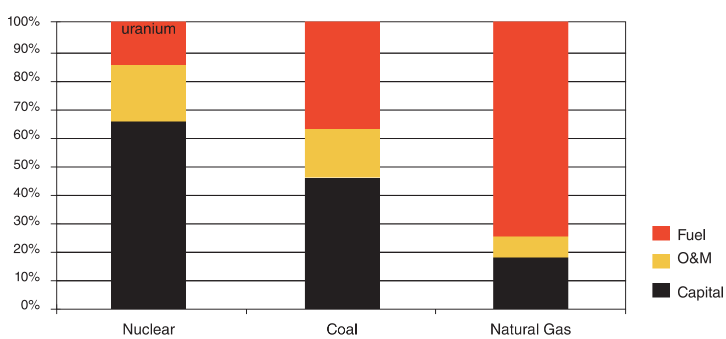


Figure 5.5 Comparative cost structures by fuel type

The range of levelised generating costs of new electricity generating capacities is illustrated in **Figure 5.5**.

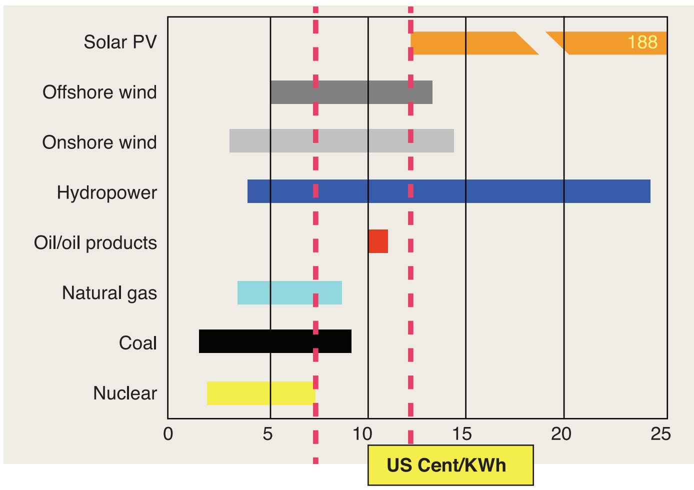


Figure 5.6 Generating costs of new electricity generating capacities

The energy resources reserves data is illustrated in **Figure 5.7**. The figure does not account for thorium and uranium from seawater.

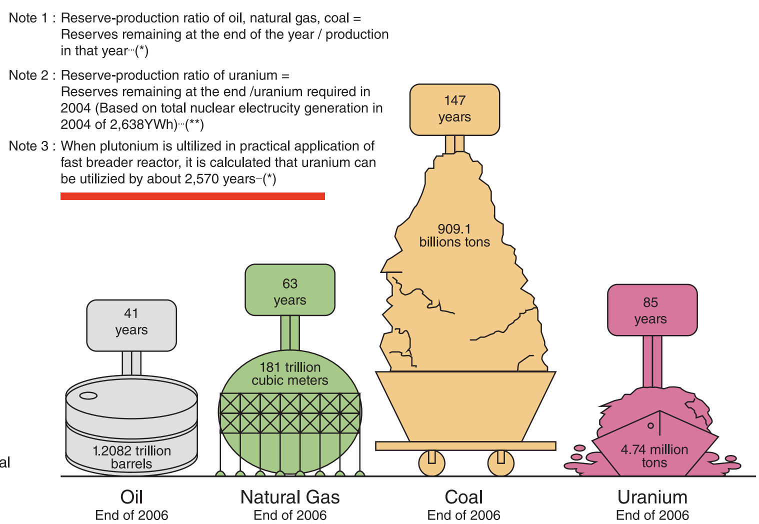


Figure 5.7 Proved reserves of energy resources

Nuclear energy has a low life cycle carbon burden and is more competitive if a carbon penalty is imposed than alternative commercial energy sources. The GHG emission level from power generation sources is indicated in **Figure 5.8**.

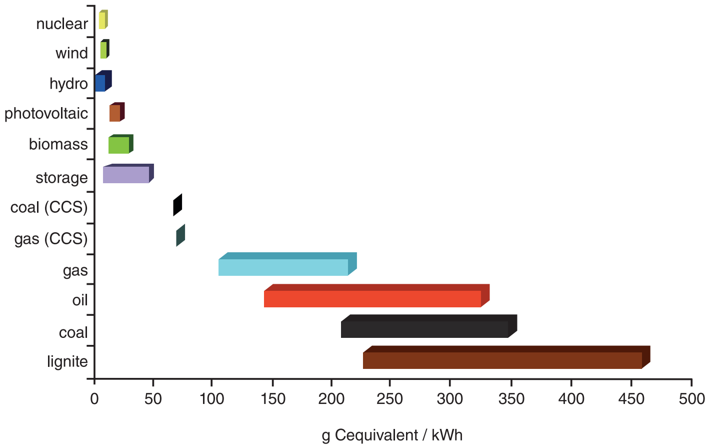


Figure 5.8 Comparative greenhouse gas (GHG) emissions from power generation sources

From these analyses, nuclear energy is well-justified in terms of supply security, environment and economics for base load. However, the main issues to be addressed are policy considerations, infrastructures such as human resource development, technology, act and regulations, and public acceptance.

In 26 June 2009, cabinet has agreed to consider nuclear energy as one of the options for electricity generation post 2020 particularly in Peninsular Malaysia. Government also will set up Nuclear Power Development Steering Committee (JPPKN) and three (3) WorkingCommittees and allocate RM25 million for a period of 3 years toimplement activities under JPPKN.

Then, in 16 July 2010, the Cabinet agreed to adopt National Nuclear Policy as a guideline for thedevelopment of nuclear sector for electricitygeneration and non-electricity generation. The main players for this policy are the Ministry of Science,Technology and Innovation (MOSTI) and Ministry of Energy, Green Technology and Water (KeTTHA). From these two decisions, a new energy policy was formulated to include nuclear as one of the option to electricity generation sources (Mohamad, Daud 2010).

5.2 MOVING UP THE VALUE CHAIN

Effectively addressing the challenges of economic growth, energy security, energy access, and environmental sustainability will require a fundamental remaking of energy production, distribution, and consumption systems around the world over the coming decades. The Global Agenda Council for the New Energy Architecture met in Dubai, United Arab Emirates in October 2011 to discuss the possible pathways to address these challenges.

Furthermore, significant change is underway in the world of energy and many factors are influencing this change – events, economic factors, energy security concerns, government policies, environmental goals and innovation are the dominant factors driving this change. Recent events include:

- The future of the nuclear sector has become uncertain after the accident at Fukushima
- The Arab Spring that has led to significant political change in the Middle East and created uncertainty about future supplies from the region
- The shale gas revolution that has started to spread from North America to other parts of the world and the technology is now being applied to tight oil

Apart from that, oil prices have reached their highest annual average since records have been kept Energy Policies Government policies in every country in the world influence both national and international energy architecture. Given the strategic significance of the industry, this has been expected. It is also expected that national interests will continue to dominate energy policies. Nonetheless, at present, there is a patchwork of policies within most nations and internationally.

Leaders from across the energy spectrum – oil and gas, power generation and low-carbon technologies – should join forces to develop a coherent policy framework for the future. The framework should be based on core principles that address energy security, economic growth and sustainability. Policies supporting the transition to a lower carbon future should be continued, but there must be realism about the role that the fossil fuel industry will continue to play for the foreseeable future to help achieve energy security and economic growth.

At the root of all policies is the fundamental belief that open borders enhance diversity and security of energy supplies. The global energy system has shown its resilience in the face of crisis and disruptions and any attempts to create barriers should be discouraged. To meet the future demand for energy, investments in excess of USD1 trillion per year will be required for the foreseeable future. This presents a significant opportunity for job creation in all parts of the energy sector and policies that support investments in the energy sector should be encouraged.

5.2.1 ENERGY EFFICIENCY

According to the International Energy Agency's 2011 World Energy Outlook, global energy demand is expected to increase by one-third from 2011 to 2035. Demand-side management is needed to curb the increase as much as possible, with energy efficiency holding the key. Significant improvements in energy efficiency are possible with known technologies. Both transportation and power generation make use of less than one-third of their primary energy input. It is well-known that deployment of energy efficiency technologies requires up front capital investment that is paid back over a period of time. There are many other market challenges such as asymmetric information flow and the 'principal-agent' problem. There is a lack of a coherent policy framework to address energy efficiency across the world. In the current economic conditions, a focus on energy efficiency is good for everyone – policy-makers, consumers and businesses.

Hence, energy industry leaders should reaffirm their commitment to driving improvements in energy efficiency as a core pillar of the future energy architecture around the world. Policy-makers should also commit to removing barriers for the deployment of new technologies that provide cost-effective solutions to improve energy efficiency. If the leading players in the energy industry do not commit themselves to greater energy efficiency and other demand side improvements, we should expect to see the growth of new entrants from other industries (such as IT), as well as new companies that are starting to capitalise on business opportunities in this space.

5.2.2 CLIMATE CHANGE

According to the IEA, global energy-related emissions of CO2 have increased by 5.3% to a record 30.4 gigatonnes in 2010. If this trend continues, it is very likely that the global average greenhouse gas concentrations will exceed 450 ppm. Since the start of the Great Recession, tackling climate change has become increasingly difficult due to fiscal challenges faced by many governments around the world. There is a growing recognition of the need for 'adaptation' as well as 'mitigation', as witnessed during COP-17 in Durban. At the same time, there is a spurt in innovation in low-carbon energy technologies. The biggest challenge these start-ups face is a lack of capital investment for scaling up their technologies and a lack of understanding of the energy industry structure.

Thus, a rapid deployment and scale up of new innovations requires closer partnerships between the incumbents and new entrants. Incumbents should increase their investments in new high-risk, low-probability technologies and new entrants should leverage the experience and expertise of the incumbents. In the current economic climate, lack of financing has become a major impediment for the scale up and rapid deployment of new technologies. Energy industry leaders should become the catalysts for these partnerships.

5.2.3 INNOVATION

This decade is crucial for evaluating the multiple pathways to a different and more sustainable energy future. The world is relying on major technological innovations in the energy sector to create this future.

The large capital stock on both the demand and supply side of the energy equation makes revolutionary change nearly impossible.

Nevertheless, the energy sector should strive for fast evolution and rapid scale up of new technologies, from laboratory to large-scale applications. This will require significant new investments in technology development, a new generation of skilled workforces, and new plants and equipment. These investments will enable us to scale up new ideas and identify the technologies that can grow from a USD50 million start-up to a USD1 billion business. Industry leaders and policy makers should develop a common framework for energy sector innovation and commit the investments required to tackle this challenge.

5.2.4 A CONCEPTUAL FRAMEWORK FOR UNDERSTANDING ENERGY ARCHITECTURE

Energy architecture is defined as the integrated physical system of energy sources, carriers and demand sectors shaped by government, industry and civil society. Energy architecture conceptualisation can be seen in **Figure 5.9**. While this is a greatly simplified view, it provides an overview of the complex interactions involved, underlining that a systems-based approach should be taken to managing change.

However, the boundary constraints limit performance against the three imperatives of the energy triangle. These constraints relate to both physical issues (such as hydrocarbon reserves) and social issues (such as

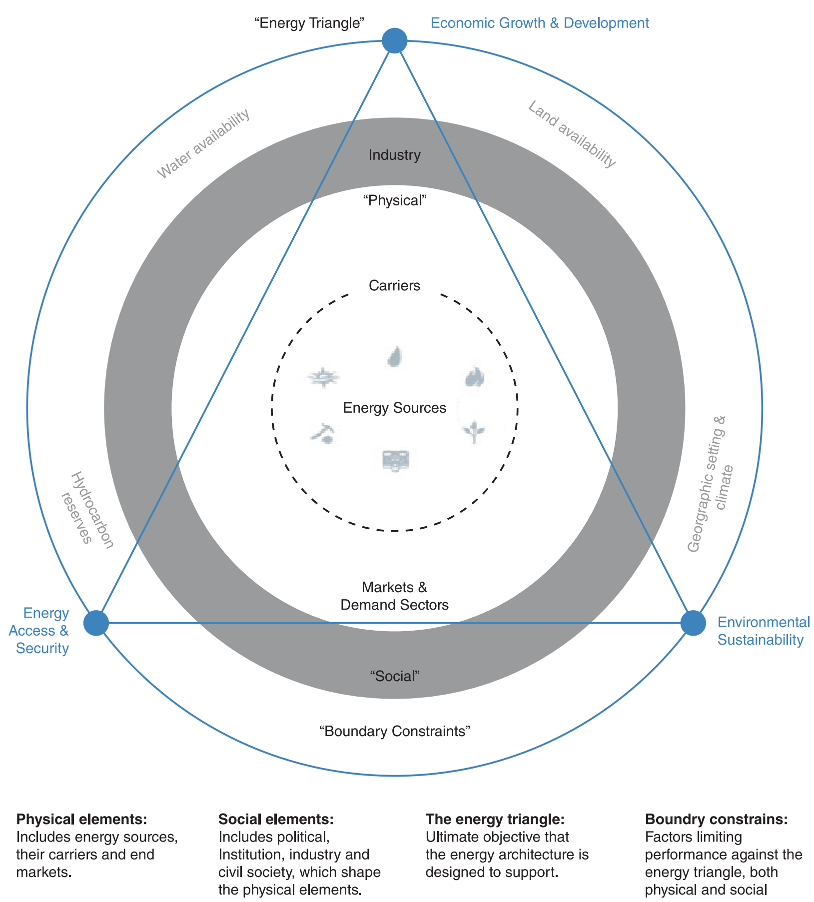


Figure 5.9 Energy architecture conceptual frameworks

the availability of human capital). Nations must consider boundary constraints, both internal and regional, when making decisions with regard to New Energy Architecture. Solar technology is a good example: crystalline solar technology is the most economical solution in areas where land availability is scarce or land costs are high; PV is the most economical solution in locations where land is abundantly available as well as in high temperature locations; and, Concentrated Solar Power (CSP) requires availability of water and direct insulation.

However, the understanding of boundary constraints changes over time. For instance, the decision of the US to pursue a concerted drive for liquefied natural gas (LNG) re-gasification capacity in the early part of this decade was based on an assumption that American energy architecture was constrained by a lack of gas reserves. That picture now looks very different, following the discovery of shale gas reserves.

Energy architecture underpins economic growth, and is a principal platform for human development and social welfare. It is interlinked with other aspects of critical infrastructure and provides an essential input into many economic processes. The affordability of energy for private consumers and the impact of energy costs on business competitiveness are major issues. Pricing is central to sending appropriate signals to consumers to reflect the true costs of energy and to producers to ensure a viable, responsive energy industry that invests in exploration, production, transformation and distribution.

The production, transformation and consumption of energy are associated with significant negative environmental externalities. To illustrate, global attention is currently focused on climate change, with growing scientific evidence suggesting that failure to limit global warming to an increase of 2°C above pre-industrial levels would make it difficult to avoid potentially irreversible changes to the earth's ability to sustain human development (IPCC 2007).

Therefore, a range of further issues relating to environmental degradation and the energy sector remain of continuing concern, including water scarcity and air pollution. The secure supply of energy is subject to a number of risks and disruptions. Principal concerns relate to the reliability of networks for transmitting and distributing energy, and the vulnerability to interruptions of supply, particularly for countries unduly dependent on a limited range of sources. Energy security is also about relations among nations, how they interact with one another, and how energy impacts their overall national security (Yergin D 2011).

Here, we extend that definition to include the provision of adequate access to all parts of the population, in recognition of the importance of tackling energy poverty in many nations in the developing world. The financial crisis reminded the world of the intrinsic link between energy and the economy. The International Energy Agency (IEA) has highlighted the important role that the run-up in oil prices from 2003 to mid-2008 played in the global economic downturn (World Energy Outlook 2009) and there is a range of literature documenting the connection between hikes in oil prices and the recession (J et. al).

In the resultant downturn there has been a pressing need for affordable energy to drive recovery through economic growth. Oil prices of around USD 100/bbl are weighing down on the fragile macroeconomic and financial situation in the OECD, pressuring national budgets in non-OECD countries and encouraging price increases in other commodities. As economic concerns have grown over the course of the past year, the pressing need to solve the global economic situation has taken priority over discussions relating to environmental sustainability (WEF 2011). With rising national debt prompting budget cuts in many countries, some governments are questioning whether they can continue to fund the clean technology programmes and financial support mechanisms that have helped foster innovation in this field. For instance, the severe impact of the economic downturn on Spain led the government to retroactively reduce the feed-in-tariff for solar PV by 30% to enable the government some 'leeway' in keeping energy prices at a moderate level.

5.2.5 CONCEPT AND CONSIDERATION

As Malaysia enters the next stage in its development to a high-income nation, the manufacturing sector will yet again need to play a prominent role in securing and enhancing the nation's prosperity. Doing so in today's world of heightened competition, it will require a change of emphasis. Malaysia's prospective comparative advantage in manufacturing will need to be increasingly redefined in terms of unique value rather than low cost. This will require Malaysian companies to step up to the fore through innovation and the building of a "Made in Malaysia" brand. It will also require domestic companies to better link up with the well-established base of foreign multinational manufacturers, so as to extract greater value added from Malaysia's integration in cross-border production networking.

For Malaysia to fulfil its high-income aspiration, it will need to move up the value chain. This involving the process of shifting the productive activity of a nation, an industry or a firm into those goods and services that generate higher value added. Moving up the value chain is a highly complex undertaking. It requires a fundamental reorientation towards innovation as the fundamental driver of growth, supported by a healthy level of investment in human and physical capital. This process should not be confused with simply producing the same mix of products more efficiently and neither should it be construed as implying a shift in focus towards anything high-tech.

Added to that, moving up the value chain also entails new, more complex, and more skill-intensive activities in the manufacturing of products. It requires conducting these at world-class standards of quality, productivity and competitiveness. As long as higher value is created, it does not matter whether these final products are low-tech, medium-tech, or high-tech.

In short, it concerns the process of shifting productive activity of a nation, an industry or a firm towards the production of goods and services that generate higher value added. While on the surface this might come across as a fairly straightforward process, moving up the value chain is an inherently complex undertaking. Hence, the process requires a fundamental shift in the sources of growth and competitiveness. For that, competitiveness can no longer be measured merely in terms of the volume of goods and services that can be produced at the lowest possible cost. Instead, it needs to be measured by the amount of domestic value added that can be generated by globally competitive firms operating in Malaysia. This in turn necessitates a reorientation towards innovation as the fundamental driver of growth, supported by a healthy level of quality investment in human and physical capital.

In addition, in moving up the value chain it should not be confused with the mere production of the same mix of goods and services in more efficient ways. To see why this is not necessarily the case, it is useful to provide the example of Malaysia's solar industry. The solar panel producers currently operating in Malaysia all employing world class, automated assembly operations. The workers in these factories are probably as efficient and productive as the workers in any solar panel factory in the world. But if most of the workers in those factories are merely tending imported automated machines and generating little value added during the production process, their world class efficiency, measured in terms of the hourly (or weekly, monthly, or annual) value or vol. of photovoltaic (PV) cells or panels produced per worker, will not move Malaysia towards high-income status.

In a similar vein, moving up the value chain should not be confused with shifting the composition of output from low-tech to high-tech goods and services. How much value added a country generates is much more important than whether the final product is classified as low-tech, medium-tech, or high-tech (D. Ferranti *et al.* 2002). Hence, if value added is high, even resource-based exports can translate into higher profits, better-paid jobs, and higher standards of living. But if the value added is low, even a high percentage of high tech exports need not provide a sufficiently large boost to per capita income. As the chart below illustrates, Argentina, Mexico, Chile and Brazil have all much higher per capita income levels than several Asian countries with much higher levels of high-tech exports (measured as a % of total manufactured exports). These countries also generate much higher value added per worker in agriculture, industry, and services, which is the key to their relative success.

The assertion that high-technology need not correlate with high income epitomises Malaysia's dilemma. As the following chart indicates, Malaysia has a higher share of high-tech exports than compared to the United States, Singapore, South Korea and Finland. And yet, Malaysia's per capita income level is significantly lower. The reason is that Malaysia historically specialised in low-wage, low-value added assembly operations, whereas countries like Singapore, the United States, South Korea, and Finland are specialised in higher-value additions,knowledge-intensive design, engineering, branding, and marketing functions. Hence, the critical task for Malaysia is therefore not necessarily to switch the sectoral composition of what it does but rather to extract greater value from whatever it does. In other words, what matters most for moving up the value chain is not whether the final product is labelled high tech, low tech, or natural resources, but rather the amount of value added generated in Malaysia.

5.3 CURRENT STATUS OF MALAYSIAN POWER SYSTEM

5.3.1 SUMMARY OF GENERATION CAPACITY, DEMAND AND GENERATION

The installed capacity of electricity generation plants is quite high compared to the demands and generation. According to the data of Energy Commission Malaysia in 2010, the installed capacity was 24275 MW. The maximum demand and generation were 16943 MW and 11562 MW, respectively.

Table 5.2 Generation capacity, maximum demand and Actual generation in 2010

Installed capacity (MW)in 2010	Maximum Demand (MW)in 2010	Generation (MW)in 2010
24275	16943	16943

5.3.2 GENERATION SYSTEM

The National Grid of Malaysia is the high-voltage electric power transmissionnetwork in Peninsular Malaysia. It is operated and owned by Tenaga Nasional Berhad (TNB) by its Transmission Division (TNB). There are two other electrical grids in Sabah and Sarawak operated by Sabah Electricity Sdn Bhd and Sarawak Electricity Supply Corporation, respectively.

The system spans the whole of Peninsular Malaysia, connecting electricity generation stations owned by Tenaga Nasional Berhad (TNB) and Independent Power Producers (IPPs) to energy consumers. A small number of consumers, mainly steel mills and shopping malls also take power directly from the National Grid. It is the largest Electric utility company in Malaysia and also the largest power company in Southeast Asia with RM69.8 billion worth of assets. It serves over seven million customers throughout Peninsular Malaysia and also the eastern State of Sabah through Sabah Electricity Sdn Bhd.

TNB's core activities are in the generation, transmission and distribution of electricity (TNB 2013). Other activities include repairing, testing and maintaining power plants, providing engineering, procurement and construction services for power plants related products, assembling and manufacturing high voltage switchgears, coal mining and trading. Operations are carried out in Malaysia, Mauritius,Pakistan, India and Indonesia.

5.3.2.1 HYDROPOWER

a. Peninsular Malaysia

Tenaga Nasional Berhad operates three hydroelectric schemes in the peninsular with an installed generating capacity of 1,911 megawatts (MW). They are the Sungai Perak, Terengganu, and Cameron Highlands hydroelectric schemes; with 21 dams in operation. A number of Independent Power Producers also own and operate several small hydro plants. Namely, the Sungai

Perak hydroelectric schemes, with 649 MW installed capacity, are as follows:

- Sultan Azlan Shah Bersia Power Station 72 MW
- Chenderoh Power Station 40.5 MW
- Sultan Azlan Shah Kenering Power Station 120 MW
- Sungai Piah Upper Power Station 14.6 MW
- Sungai Piah Lower Power Station 54 MW
- Temenggor Power Station 348 MW Sungai Terengganu hydroelectric scheme, with 400 MW installed capacity
- Sultan Mahmud Power Station 400 MW

  Sungai Pergau hydroelectric scheme, with 600 MW installed capacity

- Sultan Ismail Petra Power Station Pergau Dam 600 MW

The Cameron Highlands hydroelectric scheme, with 262 MW installed capacity

- Sultan Yusof Jor Power Station 100 M
- Sultan Idris Woh Power Station 150 MW
- Odak Power Station 4.2 MW
- Habu Power Station 5.5 MW
- Kampong Raja Power Station 0.8 MW
- Kampong Terla Power Station 0.5 MW
- Robinson Falls Power Station 0.9 MW.

Independent Hydroelectric Schemes

- Sg Kenerong Small Hydro Power Station in Kelantan at Sungai Kenerong, 20 MW

It is owned by Musteq Hydro Sdn Bhd, a subsidiary of Eden Inc. Berhad.

b. Sabah and Sarawak

- Bakun Dam 2400 MW
- Batang Ai Dam at Lubok Antu, Sarawak 100 MW
- Murum Dam in Sarawak 944 MW (Under construction)
- Tenom Pangi Dam at Tenom, Sabah 66 MW

c. Bakun Dam

The Bakun Dam is an embankment dam located in Sarawak, Malaysia on theBalui River, a tributary or source of the Rajang River and some sixty kilometres west of Belaga. As part of the project, the second tallest concrete-faced rockfill dam in the world would be built. It is planned to generate 2,400 megawatts (MW) of electricity once completed.

The purpose for the dam was to meet growing demand for electricity. However, most of this demand is in Peninsular Malaysia and not East Malaysia, where the dam is located. Even in Peninsular Malaysia, however, there is an over-supply of electricity, with Tenaga Nasional Berhad being locked into unfavourable purchasing agreements with Independent Power Producers. The original idea was to have 30% of the generated capacity consumed in East Malaysia and the rest sent to Peninsular Malaysia. This plan envisioned 730 km of overhead HVDC transmission lines in East Malaysia, 670 km of undersea HVDC cable, and 300 km of HVDC transmission line in Peninsular Malaysia.

Future plans for the dam include connecting it to an envisioned Trans-BorneoPower Grid Interconnection, which would be a grid to supply power to Sarawak, Sabah, Brunei, and Kalimantan (Indonesia). There have been mentions of this grid made within ASEAN meetings but any party has taken no actions. Bakun Dam came online on 6 August, 2011.

There are four major transmission lines sections: The first consists of an HVAC double circuit overhead lines running over a distance of 160 km from Bakun Dam to Similajau Static Inverter Plant, situated east of Bintulu and is planned beside the HVDC also the Sarawak State electricity grid which is operated by Sarawak Electricity Supply Corporation.

The next three sections consist of a bipolar HVDC 500 kV-line. The first section of this line running from Similajau Static Inverter Plant to Kampung Pueh on Borneo will be implemented as an overhead line with a length of 670 km. The next section is the submarine cable between Kampung Pueh to Tanjung Leman, Johor. It will have a length of 670 km. It is planned to be implemented by 3 or 4 parallelised cables each with a transmission capacity of 700 MW.

The last section on Malaysia peninsular will consist of an overhead DC powerline running from Tanjung Leman to the static inverter plant at Bentong. As part of the transmission work, two converter stations will be built at Bakun and Tanjung Tenggara. The HVDC lines will connect to the National Grid, Malaysia operated by Tenaga Nasional Berhad.

5.3.2.2 GAS-FIRED

Table 5.3 List of gas-fired plants in Malaysia. GT - Gas Turbine unit(s); ST - Steam Turbine unit(s) (TNB 2013)

Plant	State	MW	Type	Owner/operator
Connaught Bridge Power Station	Selangor at Klang	832	Combined cycle (1 ST, 2 GT), open cycle (4 GT)	Tenaga Nasional Berhad
Genting Sanyen Kuala Langat Power Plant	Selangor at Kuala Langat	720	Combined cycle	Genting Sanyen Power Sdn Bhd.
Karambunai Power Station	Sabah at Karambunai	120	Open cycle (4 GT)	Ranhill Powertron Sdn Bhd, a subsidiary of Ranhill Berhad
Lumut GB3 Power Station	Perak at Pantai Remis	651	Combined cycle (1 ST), open cycle (3 GT)	GB3 Sdn Bhd, a subsidiary of Malakoff
Lumut Power Station	Perak at Pantai Remis	1,303	Combined cycle (6 GT, 2 ST)[2]	Segari Energy Ventures Sdn Bhd, a subsidiary of Malakoff
Nur Generation Plants	Kedah in Kulim High-Tech Industrial Park	220	Combined cycle (4 GT, 2 ST)	Nur Generation Sdn Bhd
Paka power station	Terengganu at Paka	808	Combined cycle (4 GT, 2 ST)	YTL Power International Berhad
Pasir Gudang power station	Johor at Pasir Gudang	404	Combined cycle (2 GT, 1ST)	YTL Power International Berhad

PETRONAS Gas Centralised Utilities Facilities (CUF)	Pahang (Gebeng-Kerteh)	324	Cogen(9 GT)	PETRONAS Gas Berhad
Port Dickson Power Station	Negeri Sembilan in Port Dickson	440	Open cycle (4 GT)	Malakoff Berhad
Prai power station	Penang at Perai	350	Single shaft combine cycle (1 GT, 1 ST)	Prai Power Sdn Bhd, a subsidiary of Malakoff
Putrajaya Power Station	Selangor at Serdang	625	Open cycle (5 GT)	Tenaga Nasional Berhad
Sarawak Power Generation Plant	Sarawak at Bintulu	220	Open cycle (2 GT)	Sarawak Power Generation Sdn Bhd, a subsidiary ofSarawak Energy Berhad
Sepanggar Bay Power Plant	Sabah at Kota Kinabalu Industrial Park	100	Combined cycle	Sepangar Bay Power Corporation Sdn Bhd
Sultan Iskandar Power Station	Johor at Pasir Gudang	729	Thermal (2 ST), combined cycle (2 GT, 1 ST), open cycle (2 GT)	Tenaga Nasional Berhad
Sultan Ismail Power Station	Terengganu at Paka	1,136	Combined cycle (8 GT, 4 ST)	Tenaga Nasional Berhad
Tanjung Kling Power Station	Malacca at Tanjung Kling	330	Combined cycle (2 GT, 1 ST)	Pahlawan Power, a subsidiary of Powertek
Telok Gong Power Station 1	Malacca at Telok Gong	440	Open cycle (4 GT)	Powertek
Telok Gong Power Station 2	Malacca at Telok Gong	720	Combined cycle (2 GT, 1ST)	Panglima Power, a subsidiary of Powertek
Teknologi Tenaga Perlis Consortium	Perlis at Kuala Sungai Baru	650	Combined cycle	Teknologi Tenaga Perlis Consortium Sdn Bhd / Global E-Technic Sdn Bhd
Tuanku Jaafar Power Station	Negeri Sembilan at Port Dickson	1,500	Combined cycle (4 GT, 2 ST)	Tenaga Nasional Berhad

5.3.2.3. COAL-FIRED (OR COMBINED GAS/COAL)

Table 5.4 List of coal-fired plants in Malaysia ST - Steam Turbine unit(s) (TNB 2013)

Plant	State	MW	Type	Owner/operator
Jimah Power Station	Negeri Sembilan at Lukut	1,400	Thermal (2 ST)	Jimah Energy Ventures Sdn Bhd
Manjung Power Station	Perak at Manjung	2,295	Thermal (3 ST)	TNB Janamanjung Sdn Bhd
PPLS Power Generation Plant	Sarawak inKuching	110	Thermal (2 units)	PPLS Power Generation, a subsidiary of Sarawak Energy Berhad
Sejingkat Power Corporation Plant	Sarawak atKuching	100	Thermal	Sejingkat Power Corporation Sdn Bhd, a subsidiary ofSarawak Energy Berhad
Sultan Salahuddin Abdul Aziz Shah Power Station	Selangor at Kapar	2,420	Thermal (6 ST), open cycle (2 GT), natural gas and coal with oil backup	Kapar Energy Ventures Sdn Bhd
Tanjung Bin Power Station	Johor at Pontian	2,100	Thermal (3 ST)	Tanjong Bin Power Sdn Bhd, a subsidiary of Malakoff

5.3.2.4 OIL-FIRED

Table 5.5 List of oil-fired plants in Malaysia (TNB 2013)

Plant	State	MW	Type	Owner/operator
Gelugor Power Station	Penang at Teluk Ewa	398	Combined cycle	Tenaga Nasional Berhad
Melawa Power Station	Sabah in Melawa	50	4 diesel engines	ARL Tenaga Sdn Bhd
Sandakan Power Corporation Plant	Sabah at Sandakan	34	4 diesel engines	Sandakan Power Corporation Sdn Bhd
Stratavest Power Station	Sabah at Sandakan	60	4 diesel engines	Stratavest Sdn Bhd
Tawau Power Plant	Sabah at Tawau	36	3 diesel engines	Serudong Power Sdn Bhd

Table 5.6 List of biomass plants in Malaysia (TNB 2013)

Plant/owner/operator	State	MW	Type	Fuel
Bumibio Power Sdn Bhd (planning approved 2001)	Perak at Pantai Remis	6	Steam turbines	Empty fruit bunch
Jana Landfill Sdn Bhd	Selangor at Seri Kembangan	2	Gas turbines	Biogas
TSH Bio Energy Sdn Bhd	Sabah at Tawau	14	Steam turbines	Empty fruit bunch
Potensi Gaya Sdn Bhd (planning approved 2003)	Sabah at Tawau	7	Steam turbines	Empty fruit bunch
Alaff Ekspresi Sdn Bhd (planning approved 2003)	Sabah at Tawau	8	Steam turbines	Empty fruit bunch
Naluri Ventures Sdn Bhd (planning approved 2005)	Johor at Pasir Gudang	12	Steam turbines	Empty fruit bunch
Seguntor Bioenergy Sdn Bhd (planning approved 2007)	Sabah at Sandakan	11.5	Steam turbines	Empty fruit bunch
Kina Biopower Sdn Bhd (planning approved 2007)	Sabah at Sandakan	11.5	Steam turbines	Empty fruit bunch
Recycle Energy Sdn Bhd (commercial operation 2009)	Selangor at Semenyih	8.9	Steam turbine	Refuse-derived fuel

5.3.2.5 HYBRID POWER STATIONS

Pulau Perhentian Kecil, Terengganu with a combined capacity of 650 kilowatts:

- Two 100 kW wind turbines
- One 100 kW solar panels
- Two diesel generators capable of 200 and 150 kW respectively

***Renewable Energy (RE) Projects*:**

Great effort and initiatives have been made government to follow the footsteps of developed world on sustainable and greener technologies. This effort can obviously be seen in the funding of research by government universities around Malaysia, as well as organising important conferences of sustainable technology. One of the most important is the International Greentech and ECO products Exhibition and Conference by Malaysia IGEM.

Besides that, exemptions have been made for companies generating RE from payment of Import duty and/or sales tax on machinery, equipment, materials, spare parts, and consumables. These exemptions come from income tax (25% from 2009 onwards) on 100% of statutory income for 10 years have also been provided (KeTTHA 2009).

Furthermore, The Malaysia Energy Information Hubs (MEIH) managed by the Energy Commission (EC) of Malaysia, aims to establish a comprehensive national energy database and distribution of energy statistics in Malaysia to local and international stakeholders and the public (MEIH 2013). Moreover, several major projects are under development by TNB, while others are inoperation supplying to the main grid in Peninsular Malaysia, Sabah and Sarawak, which could bolster hydroelectric and biomass power production.

Hydroelectric power is effective intotal electric capacity and generation. It is going through significant growth, as per **Figure 2**. In contrast, most of the hydro facilities in Peninsular Malaysia are small or medium in size. However, Sarawak has the most hydroelectric potential of all the regions as part of the government's Sarawak Corridor of Renewable Energy programme. In 2012, hydroelectric capacity was about 35% of Sarawak's power capacity and is anticipated to expand to an 80% share by 2020, according to the government of Sarawak (MEIH 2013). In Recent years TNB has sign up an agreement for the purchase of electricity generated by a small RE (Renewable Energy) power project developed by Achi Jaya Plantations Sdn Bhd under the SREP Programme (Small Renewable Energy Programme) (TNB 2009).

5.3.3 TRANSMISSION SYSTEM

More than 420 transmission substations in the Peninsular are linked together by approximately 11,000 kmof transmission lines operating at 132, 275 and 500 kilovolts (kV). The 500 kV transmission systems is the single largest transmission system to be ever developed in Malaysia. It was initiated in 1995. Phase 1 involved the design and construction of the 500kV overhead transmission lines from Gurun, Kedah in the North along the west coast to Kapar, in the central region, and from Pasir Gudang to Yong Peng, on the south of Peninsular Malaysia.

The total distance covered for the 500 kV transmission lines is 522 km and the 275 kV portion is 73 km. Of the lines constructed, only the Bukit Tarek to Kapar sections had been energised at 500 kV. The remaining lines are presently energised at 275 kV. Following this, in order to cater to additional power transmission requirements from the 2,100 megawatt (MW) Manjung Power Station, the 500 kV system was extended from Bukit Tarek to Air Tawar and from Air Tawar to Manjung Power Station. In 2006, the 500 kV lines between Bukit Batu and Tanjung Bin were commissioned to carry the power generated by the 2,100 MW Tanjung Bin Power Station.

Main Transmission Grid
500kV / 275kV / 132kV of approximately
- 19,000 circuit-kilometers of overhead transmission lines
- 780 circuit-kilometers of underground transmission cables
- 385 transmission substations with transformation capacity of 83,000 MVA

Cross-Border Interconnection
- 300kV HVDC P. Malaysia - Thailand (300MW)
- 132kV HVAC P. Malaysia - Thailand (80MW)
- 275kV HVAC link P. Malaysia - Singapore (450MW)

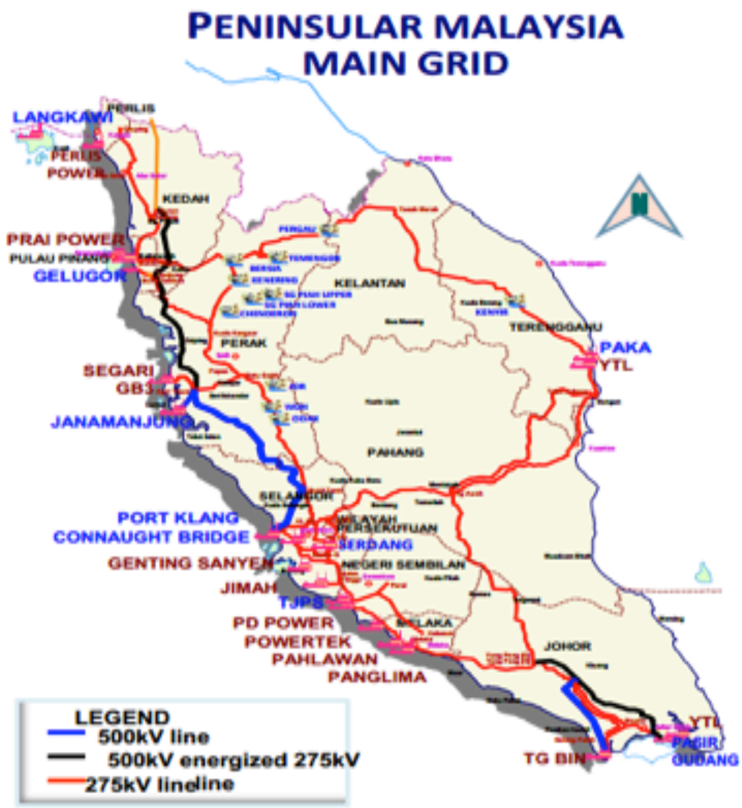


Figure 5.10 Overview of Transmission power grids

Apart from that, a project involving laying a 730 km high-voltage direct current transmission line and a 670 km undersea cable for the 2,400-megawatt Bakun hydroelectric dam has been considered. This may connect all three of Malaysia's electric utility companies with state grids: Tenaga Nasional Berhad (TNB), Sarawak Electricity Supply Corporation (SESCO) and Sabah Electricity Sdn Bhd. (SESB). Many of Sabah and Sarawak's generation plants are still not interconnected to a grid.

5.3.3.1 GRID SYSTEM IN PENINSULAR MALAYSIA

Malaysia currently has approximately 13 gigawatts (GW) of electric generation capacity, of which 84% is thermal and 16% is hydroelectric. In 2000, Malaysia generated around 63 billion kilowatt-hours of electricity. The Malaysian government expects that investment of USD9.7 billion will be required in the electric utility sector through 2010. Much of that amount will be for coal-fired plants, as the Malaysian government is promoting a shift away from the country's heavy reliance on natural gas for electric power generation.

Figure 5.11 The single largest transmission system (500 kV, 522 km) to ever be developed in Malaysia

In recent developments, TNB, the main state-owned utility, began in 1999 to divest some of its power generation units. Eventually, Malaysia expects to achieve a fully competitive power market, with generation, transmission, and distribution decoupled, but reform is still at an early stage and the exact process of the transition to a competitive market has not been decided. Nevertheless, the issue is still under study, and many observers have voiced caution in light of the experiences of other deregulated utility systems.

5.3.3.2 CONNECTION TO THAILAND

The original 117 MVA, 132 kV Single Circuit Line HVAC interconnection of 80 MW with Electricity Generating Authority of Thailand (EGAT) was commissioned in 1981, linking Bukit Ketri in the State of Perlis with Sadaoin Thailand. Subsequently, a second interconnection was made via the HVDC Thailand-Malaysia rated at 300 kV HVDC and 300 MW transmission capacities.

Figure 5.12 Grid systems in Peninsular Malaysia

5.3.3.3 CONNECTION TO SINGAPORE

In the South of Malaysia, the National Grid is connected to the transmission system of Singapore Power Limited (SP) at Senoko via two 230 kV submarine cables with a transmission capacity of 200 MW.

5.3.4 DISTRIBUTION SYSTEM

Electricity distribution is the final stage in the delivery of electricity to endusers. A distribution system's network carries electricity from the transmission system and delivers it to consumers. Typically, anetwork would include medium-voltage (1kV to 72.5 kV) powerlines, substations and pole-mounted transformers, low-voltage (less than 1 kV) distribution wiring and sometimes meters.

A transformer is a static electrical device that transfers energy by inductive coupling between its winding circuits. A transformer ranges in size; from thumbnail-sized ones used in microphones to that of units weighing hundreds of tonnes, interconnecting the power grid. Furthermore, a wide range of transformer designs are used in electronic and electric power applications. Therefore, transformers are essential for the transmission, distribution, and utilisation of electrical energy.

The distribution division conducts the distribution network operations and electricity retail operations of TNB. The division plans, constructs, operates, performs repairs and maintenance and manages the assets of the 33 kV, 22 kV, 11 kV, 5.6 kV and 415/240 Volt in the Peninsular Malaysia distribution network. Sabah Electricity provides the same function in the State of Sabah.

To conduct its electricity retailing business, it operates a network of State and area offices to purchase electricity from embedded generators, market and sell electricity, connect new supply, provide counter services, collect revenues, operate call management centres, provide supply restoration services, and implements customer and government relationships.

There are two types of distribution networks - radial or interconnected (see spot network). A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is typical of long rural lines with isolated load areas. An interconnected network is generally found in more urban areas and will have multiple connections to other points of supply. These points of connection are normally open but allow various configurations by the operating utility by closing and opening switches. Operation of these switches may be by remote control from a control centre or by a lineman. The benefit of the interconnected model is that in the event of a fault or required maintenance a small area of network can be isolated and the remainder kept on supply.

Within these networks there may be a mix of overhead line construction utilising traditional utility poles and wires and, increasingly, underground construction with cables and indoor or cabinet substations. However, underground distribution is significantly more expensive than overhead construction. In part to reduce this cost, underground powerlines are sometimes co-located with other utility lines in what are called common utility ducts. Distribution feeders emanating from a substation are generally controlled by a circuit breaker, which will open when a fault is detected. Automatic circuit reclosers may be installed to further segregate the feeder thus minimising the impact of faults.

5.3.5 SMART GRID SYSTEM

Smart Grids can provide smart management and increased efficiency in generation and storage, as well as being a great solution for rural areas, whether inside Peninsular Malaysia, Sabah, or Sarawak or in some islands atsea. Generally, three types of energy systems can be considered: systems running fully on diesel, systems running exclusively on renewable energy resources, and finally hybrid systems. It could supply electricity to inhabitant, military bases or tourists when it is needed and when it's far from main electricity. Nevertheless, the placing of microgrids in Malaysia will soon be carried out. (Rita *et al.* 2012; Kaygusuz 2011). However, Malaysia's effort to finding sustainable resources can be seen on encouragement of using solar water heater on roof of many buildings, using PV on some commercial and industrial factories. However, the best way to make use of these resources as well as storage will surely be a future microgrid which will be soon launched in Melaka City (Editors of EL&P 2, 2013).

5.3.5.1 TNB'S SMART GRID PROJECT

The TNB Smart Grid was launched in November 2009. TNB decided to implement Smart Grid Test Systems as demonstration projects. Three sites have been identified for the Smart Grid Test Systems:

1. Bayan Lepas (North); represents industrial area;
2. Bukit Bintang (Central); represents commercial centre; and
3. Medini (South); represents green field area.

Objectives	Initiaves
Improving operational effiecncy (e.g. higher supply reliability) Improving energy and asset effiecy	• Distribution management system • On-line condition monitoring • Distribution automation • Field Force Automation • Geographical information system • Customer information system • Customer management system
Empowering customers	• Advance metering infrastructure • Interface with building energy management system
Reduce CO2 emission	• Promote RE, EE, Co-gen, DER • Facilitate to enable connection of RE, EE, Co-gen, DER • Dynamic voltage/VAR control
Support use of PHEV	• Facilitate charging of PHEV

Figure 5.13 TNB's smart grid objectives

5.3.5.2 MELAKA PROJECT

For the Masers Energy Smart Grid City and Green Special Economic Zone, the Malaysian government selected Melaka, a small province on the Malaysian Peninsular, for the future Energy Smart Grid City Melaka and the Green Special Economic Zone Melaka projects. However, work on the development of the two smart grid projects will be initiated early in2014 (Editors of EL&P 2013).

This project is expected to bring the economic and societal benefits of smart infrastructure to Malaysia, the plan leverages the latest smart city technologies and innovations to create a 'Green Corridor' in Melaka; helping it become one of the world's leading green and low-carbon centres. The IPv6-based networks will be used by Silver Spring to launches a communications foundation, with a smart infrastructure platform to support Smart City solutions such as intelligent road lighting, traffic signal control and electric vehicle charging (Editors of EL&P 2 2013).

5.3.6 THERMAL EFFICIENCY FOR GENERATION PLANTS (PER CENT)

The thermal efficiencies of TNB electricity generation plants in Peninsular Malaysia are 40.84%, 22.3% and 27.27% for combined-cycle, open-cycle and conventional (oil/gas), respectively. The thermal efficiency of IPP Generation plants is a bit higher than TNB, as shown in tables below:

Table 5.7 Thermal efficiency of TNB generation plants

Year	Average Thermal Efficiency for TNB Generation Plant (%)		
	Combined-Cycle	Open-Cycle	Conventional (Oil/Gas)
2006	41.3	26	29.4
2007	41.5	25.9	27.8
2008	41.2	25.6	18.3
2009	41	17.4	0
2010	41.2	22.6	25.6
2011	40.84	22.3	27.27

Table 5.8 Thermal efficiency of IPP generation plants

Year	Average Thermal Efficiency for IPP Generation Plant (%)		
	Combined-Cycle	Open-Cycle	Conventional (Oil/Gas)
2006	45.3	25.6	32.5
2007	45.2	27.6	32.4
2008	44.8	25.1	32.2
2009	44.3	27.4	31.9
2010	41.9	27.3	32.3
2011	43.98	27.09	30.58

5.4 CONCLUSION

Although 1.7 billion people obtained connections to electricity between 1990 and 2010, the rate was only slightly ahead of the population growth of 1.6 billion over the same period. Electricity expansion growth will have to double to meet the 100% access target by 2030. Added to that, getting there will require an additional $45 billion invested in access every year - five times the current annual level.

Nevertheless, the carbon cost of such expansion, is low. To bring electricity to those without it would increase global carbon dioxide emissions by less than 1%. Sustainable Energy for All, a global coalition of governments, the private sector, civil society, and international organisations, aims to achieve this while also doubling the amount of renewable energy in the global energy mix from its current share of 18% to 36% by 2030.

CHAPTER 6

ENERGY GENERATION, TRANSMISSION AND DISTRIBUTION PLAN OF ACTIONS AND ROADMAP: NATIONAL OBJECTIVES STRATEGIES, NATIONAL INCENTIVE GUIDELINES, ENERGY EFFICIENCY, RESEARCH AND DEVELOPMENT INSTITUTES

6.1 PURPOSE OF THE ROADMAP

The Energy Sector's main objective is to ensure the electricity supply is efficient, safe and able to achieve expectations, to increase the efficiency of electric energy consumption and avoid electric wastage which is unproductive, to minimise the negative impact due to supply and use of electric on environment, and to increase the electricity supply industry from economic development aspect and maintain quality of life.

The principal functions of the Energy Division of the Ministry of Energy, Green Technology and Water are to formulate policies and strategies and undertake planning of the electricity supply industry, to promote energy efficiency and renewable energy, to review tariffs imposed by electricity utilities, to monitor standards of service of electricity utilities, to administer the Electricity Supply Industry Trust Account, and to monitor energy programmes and project implementation Client Charter for Energy Sector has been prepared for 3 main parts: Energy Policy Planning, Tariff revision andAllocation Withdrawal Application under Electricity Industry Trust Account (AAIBE).

6.1.1 ENERGY POLICY PLANNING

Ensure to draw effective energy policies and sustainable for people, industry, and country to attainment the objective of accelerating nation's status achievement industrial. Policies for people involve supplying enough reliable electricity. Policies for industry, on the other hand, involve a steady supply of electricity at competitive prices. Energy policies planning involve aspect of electricity supply industry restructuring, renewable power development, and national strategy for energy efficiency.

Policy planning for all three aspects above needs detailed research, and thus, should take into account comments from all related agencies. For that, the provision terms of reference, study method and research implementation determination should be determined within a period of six months from the Minister's approval period. The comments should also be obtained from stakeholders within one month through various ways such as workshop, while the policy draft based on survey results and comments from stakeholders should be obtained within two months. The Ministers Board Memorandum on policy proposal should be provided within one month from Minister's Approval. Finally, the implementation ofa policy should take place within one month from acceptance a decision (KeTTHA 2013).

6.1.2 TARIFF REVISION

Ensuring every tariff amendment proposal related fuel is processed and studied together with Energy Commission should take place every six months. Planning and Implementation Committee Meeting Electric and Tariff Supply (JPPPET) meetings should be held within two weeks from comment accession date from Energy Commission. Ministers Board Memorandum should be completed within two weeks from JPPPET date of meeting where agreement was obtained. Agencies involved, namely TNB / SESB, should be informed of the Government decision within two days of the decision accession date by the Ministers Board.

6.2 NATIONAL OBJECTIVES STRATEGIES

To achieve the national objectives, the Government is pursuing the following strategies:

6.2.1 SECURE SUPPLY

Diversification of fuel type and sources, technology, maximised use of indigenous energy resources, adequate reserve capacity to cater for contingencies, adequate reserve margin for generation, upgrading transmission and distribution networks and distributed generation (islanding);

6.2.2 SUFFICIENT SUPPLY

Forecast demand, right energy pricing and formulate plans to meet demand;

6.2.3 EFFICIENT SUPPLY

Promote competition in the electricity supply industry;

6.2.4 COST-EFFECTIVE SUPPLY

Promote competition and provide indicative supply plan to meet demand based on least cost approach using power computer software such as WASP;

6.2.5 SUSTAINABLE SUPPLY

Promote the development of renewable and co-generation as much as possible;

6.2.6 QUALITY SUPPLY (LOW HARMONICS, NO SURGES AND SPIKES, MINIMAL VARIATION IN VOLTAGE)

Match quality with customer demand with variable tariffs;

6.2.7 EFFICIENT UTILISATION OF ENERGY

Benchmarking, auditing, financial and fiscal incentives, technology development, promotion of ESCOs, Labelling, Ratings, correct pricing, energy managers;

6.2.8 MINIMISING NEGATIVE ENVIRONMENTAL IMPACTS

Monitor the impacts, improve efficiency of utilisation and conversion and promote renewable. In pursuit of the supply objective, policy initiatives, particularly with respect to crude oil and gas, have been aimed at both extending the life of domestic depletable energy resources, as well as diversification away from oil dependence to include other forms of energy sources.

The national depletion policy of 1980 was aimed at safeguarding the depleting oil reserves. The policy, aimed at major oil fields of over 400 million barrels of oil initially in place (OIIP), restricted their productions to 1.75% of OIIP. However, in 1985 the ceiling was revised to 3% in light of the fact that 1.75% was on the conservative side. As a result of this policy, the total production of crude oil is currently limited to about 650,000 barrels per day. As such, at the current production rate, proven oil reserves are expected to last another 16 years.

The national depletion policy was later extended from crude oil to include our natural gas reserves. An upper limit of 2,000 million standard cubic feet per day (mmscfd) has been imposed in Peninsular Malaysia. At the current rate of production, known natural gas reserves are expected to last for about 70 years. In 1981, the Government adopted the four-fuel strategy, complementing the national depletion policy, aimed at ensuring reliability and security of supply.

The strategy was, effectively, designed to reduce the country's overdependence on oil as the energy source. The strategy aims for a supply mix of oil, gas, hydropower and coal in energy use. As much as possible, local resources of these fuels will be used to enhance security of supply (KeTTHA 2013). In 1998, the proportion of the four fuels in power stations was 16% fuel oil, 2% diesel oil, 67% gas, 8% hydropower and 7% coal. The table below shows a comparison of fuel mix of commercial energy supply between 1990 and 1998 as shown in **Table 6.1**.

Table 6.1 A Comparison of Fuel Mix of Commercial Energy Supply between 1990 and 1998 (in ktoe)

Sectors	1990	1998
Industrial	5,885	10,121
Transport	5,387	9,793
Residential & Commercial	1,646	3,314
Non-energy	299	2,023
Agriculture	0	307
Total	13,217	25,558

Amongst the various economic subsectors, the electricity subsector has shown the greatest achievement in terms of the four fuels policy. Generation fuel mixes in this subsector for 1990 & 1998 (excluding co-generation and private licensed plants) is shown in the following **Table 6.2**.

Table 6.2 Generation fuel mixes between 1990 and 1998 (in ktoe)

FUEL	1990	1998
Fuel Oil	2,873	2,130
Diesel oil	116	275
Natural gas	1,361	8,886
Hydropower	915	1,113
Coal	813	964
Total	6,078	13,368

Being too dependent on gas currently, the electricity industry is also expected to increase its utilisation of coal at the turn of the millennium although the coal option has both environmental implications and foreign exchange implications. This is in line with the four-fuel policy, and the need to cap gas production to allow for longevity. Hydropower development is also being pursued for electricity generation, but the recent economic crisis has caused some setback to the planned increase of hydropower's share in the country's energy supply mix in the medium term.

The transport sector has been and continues to be the least diversified in terms of fuel use, as it is, it is highly oil dependent. In 1983, the Government introduced the 'Go Gas' initiative. This initiative saw limited success despite the sales tax incentives. Except for the limited electric train network in the vicinity of the Federal capital, and the proposed electric and gas-based transport modes in the proposed Putrajaya Administrative Centre, new policy-directed initiatives have been constrained to push or pull the transport sector towards greater diversification in fuel use. As in other countries, technology and costs continue to be the major constraints in Malaysia to achieve the fuel diversification objective in the transport sector. The **Table 6.3** below shows a comparison of fuel mix in the transportation sector in 1982 and 1996 (KeTTHA 2013).

Table 6.3 A Comparison of Fuel Mix in the Transportation Sector in 1982 and 1996

FUEL	1982	1996
Petroleum Products	100.0 %	99.94%
Gas	0%	0.06%

6.2.9 THE UTILISATION OBJECTIVE

To date, the Government's approach in materialising this objective is to rely heavily on the energy industry as well the consumers to exercise efficiency in energy production, transportation, conversion, utilisation and consumption through the implementation of awareness programmes.Demand side management initiatives by the utilities, particularly through tariff incentives, have had some impact on efficient utilisation and consumption. Furthermore, the Government initiatives to encourage co-generation are also aimed at promoting an efficient method for generating heat energy and electricity from a single energy source.

This also contributes to a reduction in the costs of conversion. To enhance the level of achievement of the Utilisation Objective, the market approach needs to be supplemented by the regulatory approach. Towards this end, the energy efficiency regulation is currently being formulated and it will be focusing on designation of large consumers, appointment of energy managers and equipment labelling. The Government is conscious of the need to work with the industry to promote energy efficiency in order to reduce inefficient and wasteful use of energy in industrial facilities. Towards this end, a number of industrial energy efficiency initiatives are being planned, such as an energy auditing programme, energy service companies support programme and technology demonstration programme.

6.3 ENERGY EFFICIENCY

The LEO (Low Energy Office) Building in Putrajaya was first occupied in 2004, and building energy management has been practiced since then. The building energy index in 2005 was 114kWj / m2 / year, but decreased to 104kWj / m2 / year in 2006. An energy audit was done on the Block E6 Ministry of Health and Block B6 Economic Planning Unit (EPU) of the Prime Minister's Department buildings in Putrajaya. The audit revealed that the energy index of the LEO Building was lower than conventional buildings.

The MEWC organised two seminars in 2006 to share the experience of the LEO Building and energy efficiency management, namely "Energy Efficiency in Buildings – How to Achieve Immediate Savings", on 24 January 2006, in Kuala Lumpur; and "MEWC Low Energy Office: Lessons Learnt", on 4 May 2006 in Putrajaya. The seminar on Energy Efficiency in Buildings was targeted at Government agencies and departments, local authorities, building owners and maintenance, and professional bodies in the energy industry. 200 participants attended the seminar.

The "MEWC Low Energy Office: Lessons Learnt" seminar was attended by 300 people from Government agencies and the private sector. Through programmes as such, the Ministry hopes to increase the effectiveness of energy usage among members of the public. Other continuous activities implemented under this project include monitoring the energy usage index on a monthly basis, receiving visitors, and delivering talks and preparing brochures on the LEO Building.

The LEO building won first place in the "Energy Efficient Building Best Practices Competition 2006" at the ASEAN level, under the "New and Existing Building" category. The award was presented at a special ceremony organised on 27 July 2006 in conjunction with the 24th ASEAN Energy Ministers meeting in Vientiane, Lao PDR. The Deputy Minister of Energy, Water and Communications received the award on behalf of the Malaysian (KeTTHA 2013).

6.3.1 MALAYSIAN ENERGY EFFICIENCY IMPROVEMENT PROGRAMME (MIEEIP)

This project is a continuation of the collaborative project between the Malaysian Government, Global Environmental Facility (GEF) and United Nations Development Programme (UNDP) with funding from the electricity supply industry through the Electricity Supply Industry Trust Account (AAIBE). The Ministry of Energy, Water and Communications is the co-coordinator for this project while the Malaysian Energy Centre is the implementation agency. The project has been extended to June 2007 to implement additional activities that have been identified including implementing energy audit on three (3) additional energy-intensive sectors, namely plastics, oleo chemicals, and petroleum.

The energy efficiency and conservation guidelines that were jointly developed with the Energy Commission and Malaysian Energy Centre were completed in 2006 and scheduled for launch in 2006. The guidelines were intended to provide the industry with a guide to manage their electricity energy more efficiently and choose suitable best practices in equipment and electrical facility maintenance at their factories/premises. Under the energy audit programme, the MEEIP team hopes to conduct analysis on the audit done by ESCOs (energy services companies) in the textile and plastics sectors to further increase the efficiency of energy usage in the industry sector.

The MEEIP's biggest success in 2006 was the launch of the Heveaboard Project on 27 March 2007, by the Deputy Minister of Energy, Water and Communications. The project was an energy-saving project based on Energy Performance Contracting between an ESCO and a factory. Through the project, the factory was able to save RM70,000 on its monthly electricity bill. Apart from this, the quarterly MEEIP Newsletter was published and distributed to the industry as another effort to encourage the efficient use of energy in the industry (KeTTHA 2013).

6.3.2 CENTRE FOR EDUCATION AND TRAINING IN RENEWABLE ENERGY AND ENERGY EFFICIENCY (CETREE)

This project is a continuation of the centre for education and training in renewable energy and energy efficiency (CETREE) project that was implemented by the Malaysian Government in collaboration with DANIDA, under the Malaysia-Danish environmental cooperation programme that began in 2000. The purpose of the project is to increase the level of knowledge and awareness on the role and use of energy efficiency in education. Through this project the concept of renewable energy and energy efficiency could be absorbed into curricular activities in schools and universities.

From 22 to 24 August 2006, CETREE worked with the Ministry of Education Malaysia to organise three competitions related to renewable energy and energy efficiency, namely solar cars, cooking with solar cookers including renewable energy, and energy efficiency beach house. Indoor games were also organised, along with an inaugural exhibition by CETREE. CETREE's main exhibition that featured an energy van in a mobile exhibition was also displayed.

Apart from that, CETREE also ran energy efficiency campaigns in the local newspapers. The campaign was held from 15 December to 19 December 2006. It featured information on choosing energy efficiency equipment such as refrigerators, air conditioners, irons, electric kettles and lights. Students from schools and public institutes of higher learning from throughout the country went on learning tours to CETREE. To date, 8,260 students and 1,714 teachers and lecturers have visited CETREE, along with 14,109 members of the public. CETREE now hosts an interactive website to disseminate information on energy efficiency and renewable energy (KeTTHA 2013).

6.3.3 THE GOVERNMENT

Policy making for the energy sector resides with the following institutions per **Table 6.4**.

Table 6.4 Policy making for energy sector

INSTITUTIONS	AREAS OF JURISDICTION
Prime Minister's Department (Economic Planning Unit)	• Petroleum (oil and gas). • Privatisation of the electricity supply industry e.g. IPPS.
Ministry of Energy, Green Technology and Water	• Electricity supply industry. • Energy efficiency. • Renewable energy
Ministry of Rural Development	• Rural electricity supply.

The economic and technical regulatory functions reside with the following institutions per **Table 6.5**.

Table 6.5 Economic and technical regulatory functions

INSTITUTIONS	AREAS OF JURISDICTION
Energy Commission	Electricity in all States except Sarawak (technical including safety and economic)
Department of Occupational Health & Safety	Safety in gas sector (at reticulation stage). Safety in oil sector (upstream and downstream).
Prime Minister's Department Economic Planning Unit	Natural Gas prices.
Ministry of Domestic Trade, Co-operatives And Consumerism	Price of petroleum products.
State Governments	Exploitation of coal resources.
Ministry of International Trade and Industry	Licensing on petroleum processing activities.

6.4 ELECTRICITY SUPPLY INDUSTRY

The electricity subsector is dominated by three integrated utilities, i.e. TNB serving Peninsular Malaysia, SESB and SESCO. It was complimented by various independent power producers (IPPs), dedicated power producers and co-generators.

6.4.1 TENAGA NASIONAL BERHAD

TNB is a public listed company on the KLSE and was established in 1990 through the corporatisation of the National Electricity Board. (www.tnb.com.my). It is the largest electricity utility in Malaysia. The current total installed generation capacity in Peninsular Malaysia is 17,623 MW; with TNB holding 8,417 MW (46.8%), IPP holding 6,787 MW (38.5%) and another 2,419 MW (13.7%) jointly owned by TNB and Malakoff (via Kapar Energy Ventures, KEV). Hence, the Current Installed Generation Capacity – 17,622 MW.

However, gas remains as a major primary energy input for the electricity sector constituting 68%, with 63.8% of the installed generating plants firing on gas. Nevertheless, coal is fast gaining significance in the generation fuel mix from 11.1% in 2002 to the present 31.1%. Thus, coal, as a primary fuel will gain more significance with the commissioning of the TanjungBin and Jimah power plants by the IPP within this 9th Malaysia Plan period. Hydro contributed 13.8% for 2006 and oil acting as just standby and back-up fuel.

As part of its strategy to improve efficiency, TNB has been undergoing substantial internal restructuring since 1996 with the formation of many subsidiary companies, each entrusted with a specialised field of business. The main subsidiaries of TNB are:

- TNB Generation Sdn Bhd
- TNB Transmission Sdn Bhd
- TNB Distribution Sdn Bhd
- TNB Research Sdn Bhd
- TNB Engineers Sdn Bhd
- University Tenaga Nasional
- TNB Engineering and Consultancy Sdn Bhd
- TNB Repair and Maintenance Sdn Bhd

6.4.2 SABAH ELECTRICITY SDN BHD (SESB)

SESB was founded on 1 September, 1998 to take over the business of electricity supply from Sabah Electricity Board, a statutory body of the Federal Government, which had been supplying electricity to consumers in Sabah and Labuan. TNB and the State Government of Sabah own SESB.

6.4.3 SARAWAK ELECTRICITY SUPPLY CORPORATION (SESCO)

SESCO is a statutory authority established by the State Government of Sarawak. The Sarawak Government has a 55% ownership and Sarawak Enterprise Corporation Bhd (SECB) holds the remaining 45% shares. SESCO is an integrated utility (d) Northern Utility Resources (NUR) NUR (www.khtp.com.my) is a dedicated power producer serving the Kulim High Technology Park in Kedah, a state which is located in the north of Peninsular Malaysia. It has two subsidiary Companies, NUR Generating involved in electricity generation and NUR Distribution which is involved in electricity distribution. The capacity of this dedicated power plant is 450 MW which is implemented in 2 phases.

6.4.4 INDEPENDENT POWER PRODUCERS (IPPS)

IPPs in Malaysia generate and sell electricity in bulk to the 3 dominant utilities. The IPPs that are in operation are as follows in **Tables 6.6** and **6.7:**

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Table 6.6 IPP in Peninsular Malaysia

IPP	LOCATION	CAPACITY (MW)	DATE OF ISSUE OF LICENSE
YTL Power Generation	Paka, Terengganu & Pasir Gudang, Johor	808 404	7 April 1993
Segari Energy Ventures Sdn Bhd	Lumut, Perak	1,303	15 July 1993
Powertek Sdn Bhd	Alor Gajah, Melaka	440	1 December 1993
Port Dickson Sdn Bhd	Tanjung Gemuk, Port Dickson	440	1 December 1993
Pahlawan Power Sdn Bhd	Tanjung Keling, Melaka	334	26 May 1999
Genting Sanyen Power Sdn Bhd	Kuala Langat, Selangor	720	1 July 1993
TTPC	Perlis	650	26 August 1998
Panglima	Melaka	720	7 August 2001
GB3	Lumut, Perak	640	7 August 2001
Prai Power	Seberang Prai, Penang	350	20 February 2001
KEV	Kapar, Klang	2420	1 July 2004
Janamanjung	Lumut, Perak	2100	21 May 1998
Tanjung Bin Power	Johor	2100	26 September 2003
Jimah Energy Ventures	Jimah, Port Dickson	1400	22 March 2005

Table 6.7 IPP in Sabah

IPP	LOCATION	CAPACITY (MW)	DATE OF ISSUE OF LICENSE
ARL Tenaga Sdn Bhd	Melawa	50	14 June 1994
Serudong Power Sdn Bhd	Tawau	36	31 March 1995
Powertron Resources Sdn Bhd	Karambunai	190	6 February 1997
Stratavest Sdn Bhd	Sandakan	64.4	1 October 1996
Sandakan Power Corporation Sdn Bhd	Sandakan	34	29 November 1997
SBPC	Sepanggar	66	
Powertron II	Karambunai	190	

6.4.5 SARAWAK

Sarawak does not have IPPs, but has an associated power producer named Sejingkat Power Sdn Bhd, which is a generating company, 49% owned by SESCO and the remaining 51% by Sarawak Enterprise Corporation Bhd (SECB). It is situated at Sejingkat, Sarawak and has a capacity of two units of 50MW, each fuelled by coal from Global Minerals near Kapit, Sarawak. Unit I was commissioned on 19 February, 1998, while Unit 2 was commissioned on 15 May, 1998.

6.5 RESEARCH AND DEVELOPMENT INSTITUTES

The following are several R&D institutions in Malaysia that are involved in both scientific and economic research:

6.5.1 GREENTECH MALAYSIA (FORMERLY KNOWN AS PUSAT TENAGA MALAYSIA (PTM))

PTM is an independent and non-profit organisation established in May 1998 to fulfil the need for a national energy research centre in Malaysia. Its core activities are energy planning and research, energy efficiency and technological research, development and demonstration. Their responsibilities also include data gathering. PTM also function as a one-stop energy agency for linkages with the universities, research institutions, and industries other national and international energy organisations. The following are its main functions:

1. Agent for public and private sectors
2. Guardian/repository of a national database
3. ‘think-tank’ on energy via consultancy services
4. Promoter of national energy efficiency programme
5. Coordinator and lead manager in energy research, development and demonstration projects.

6.5.2 TNB RESEARCH SDN BHD

TNB Research Sdn Bhd, a wholly owned subsidiary of TNB, was formed in March 1993 to undertake R&D activities for TNB. It provides quality assurance, laboratory testing and consultancy services in energy and environment preservation for TNB and other energy suppliers in Malaysia.

6.5.3 PETRONAS RESEARCH SCIENTIFIC SERVICES SDN BHD (PRSS)

PRSS is a subsidiary fully owned by PETRONAS which carries out R&D’s activities for the petroleum industry.

6.5.4 SIRIM BHD (SIRIM)

SIRIM is involved in R&D activities for the industrial sector. In the field of energy, its activities are focused on renewable energy and energy efficiency.

6.5.5 PROGRAMME/PROJECT

1. Centre of education and training for renewable energy and energy efficiency (CETREE);
2. Project capacity building in integrated resources planning (IRP) at government and related agencies;
3. New building project for Ministry of Energy, Green Technology and Water in Putrajaya;
4. Small Renewable Energy Programme (SREP); and
5. Demand Side Management' Project.

6.5.6 ELECTRICAL AND ELECTRONICS INDUSTRY

The Electrical and Electronics (E&E) industry is the leading sector in Malaysia's manufacturing sector, contributing significantly to the country's manufacturing output (26.94%), exports (48.7%) and employment (32.5%). In 2010, the gross output of the industry totalled RM158.7 billion (USD 50.94 billion), exports amounted to RM235.5 billion (USD 75.7 billion) and created employment opportunities for 325,696 people. The major export destinations are USA, China and Singapore while the major import destinations are Taiwan, USA and South Korea.

Over the years, Malaysia's E&E industry has developed significant capabilities and skills for the manufacture of a wide range of semiconductor devices. This is include photovoltaic cells and modules, high-end consumer electronics, and Information and Communication Technology (ICT) products. The E&E manufacturers in the country have continued to move-up the value chain to produce higher value-added products. This includes intensification of research and development efforts and the outsourcing of non-core activities domestically (KeTTHA 2013).The E&E industry in Malaysia can be categorised into the following four subsectors:

6.5.6.1 CONSUMER ELECTRONICS

This subsector includes the manufacture of LED television receivers, audiovisual products such as Blu-ray disc players/recorders, digital home theatre systems, mini disc, electronics games consoles, and digital cameras. The sector is represented by many renowned Japanese and Korean companies which have contributed significantly towards the rapid growth of the sector. Leading companies are now undertaking R&D activities in the country to support their global and Asian markets. Exports of consumer electronic products in 2011 amounted to RM22.36 billion (USD8.7 billion).

6.5.6.2 ELECTRONIC COMPONENTS

Products or activities, which fall under this subsector, comprise of semiconductor devices, passive components, printed circuits and other components such as media, substrates and connectors. The electronic component sectors are the most important subsectors, accounting for 36% of the total investments approved in the electronics sector in 2011. The subsector is mainly dominated by the semiconductor players especially MNCs, mainly undertaking the assembly and test activities.

Nevertheless, the development of the semiconductor cluster has shown a gradual increase over the years. More companies are expanding research, design and development activities in their operations with less emphasis in the manufacturing of low end products. The increase in demand for the miniaturisation and high performance devices for mobile, automotive, and green applications has further stimulated the growth of outsourcing activity in the semiconductor industry. Semiconductor products constituted of export value RM107 billion (USD34.4 billion). It contributed 93.4% of the total export of electronic components or 50.8% of the total electronics exports for 2011.

6.5.6.3 INDUSTRIAL ELECTRONICS

This subsector consists of multimedia and information technology products such as computers, computer peripherals, telecommunication products and office equipment. The Industrial electronics subsector accounted for 6% of the total investment approved in the electronics sector in 2011. In that year too, a majority of the investments approved amounting to RM2.6 billion were from Electronic Manufacturing Services (EMS) companies producing low volume - high mix products for various applications such as medical, aerospace, oil and gas, and telecommunication.

6.5.6.4 ELECTRICAL

The major electrical products produced under this subsector are lightings, solar related products and household appliances such as air-conditioners, refrigerators, washing machines and vacuum cleaners. In 2011, investments in the subsector amounted to RM9.7 billion, of which 91.4% was dominated by foreign investments while domestic investments accounted for 8.6% of the total approved investments in 2011.

With exception to the solar industry, most of the investments in the electrical subsector were from the domestic sources, especially in the production of household appliances and electrical components. Malaysia is home to many of the largest and renowned solar players such as First Solar and AUO-Sunpower. The presence of these MNCs has contributed to the development of various products under the solar cluster.

The growing awareness of the importance of the green technology including renewable energy has led to the introduction of the LED roadmap by the Malaysian Government. This has spurred the growth of the LED industry and opens up new opportunities for both local and foreign investors in developing Malaysia's LED industry. The introduction of the Feed-in-Tariff (FiT) in 2011 has encouraged the usage of renewable energy in the country. This mechanism enables electricity produced from indigenous renewable energy resources to be sold to power utilities at a fixed premium price for a specific duration.

6.6 CARBON NEUTRAL COMMUNITY

Carbon neutral, or having a net zero carbon footprint, refers to achieving net zero carbon emissions by balancing a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough carbon credits to make up for the difference. It is used in the context of carbon dioxide releasing processes associated with transportation, energy production, and industrial processes such as production of carbon neutral fuel.

The carbon neutrality concept may be extended to include other GHG measured in terms of their carbon dioxide equivalence. The impact a GHG has on the atmosphere expressed in the equivalent amount of CO_2. The term climate neutral reflects the broader inclusiveness of other greenhouse gases in climate change, even if CO_2, is the most abundant, encompassing other greenhouse gases regulated by the Kyoto Protocol, namely methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), and sulphur hexafluoride (SF_6).

The best practice for organisations and individuals seeking carbon neutral status entails reducing and/or avoiding carbon emissions first so that only unavoidable emissions are offset. Carbon neutral status is commonly achieved in two ways:

- Balancing carbon dioxide released into the atmosphere from burning fossil fuels, with renewable energy that creates a similar amount of useful energy, so that the carbon emissions are compensated, or alternatively using only renewable energies that don't produce any carbon dioxide (also called a post-carbon economy).

- Carbon offsetting by paying others to remove or sequester 100% of the carbon dioxide emitted from the atmosphere. For example, by planting trees or by funding "carbon projects" that should lead to the prevention of future greenhouse gas emissions, or by buying carbon credits to remove (or 'retire') them through carbon trading. While carbon offsetting is often used alongside energy conservation measures to minimise energy use, some criticises the practice.

6.6.1 CASE STUDY 1: SABAH ENERGY ISSUES

Renewable energy from solar and wind turbine is not only an excellent power alternative for the future, but it can also revolutionise electricity generation in Sabah. Sabah had its own uniqueness as it endowed was rich natural resources which could be used to generate renewable energy and contribute to economic development. The projects, the Application of Wind Technology System for Energy Generation and the Sustainable Thin Film PV Building and the Renewable Energy Generation, have been entrusted to SIRIM Bhd by the Ministry of Science, Technology and Innovation for research and development.

Overall, the projects can generate 25 kW of wind turbine power and 9.8 kW of solar energy. The power generated can light up a resort near the project site in Tanjung Simpang Mengayau and can be supplied and stored in a battery system. It can also bring cheer to the many rural residents who live far away from grid areas. In the long-term, renewable energy can become a big alternative to the current practice of generating electricity from fuel oil, charcoal, diesel and hydro reservoirs which incur huge operational costs.

6.6.2 CASE STUDY 2: DISTRIBUTED GRID IN SABAH AND SARAWAK

Distributed Grid (DG) consists of a range of smaller-scale and modular devices designed to provide electricity, and sometimes also thermal energy, in locations close to consumers. They include fossil and renewable energy technologies (e.g. photovoltaic arrays, wind turbines, microturbines, reciprocating engines, fuel cells, combustion turbines, and steam turbines); energy storage devices (e.g. batteries and flywheels); and combined heat and power systems. Distributed grid offers solutions to many of the nation's most pressing energy and electric power problems, including blackouts and brownouts, energy security concerns, power quality issues, tighter emissions standards, transmission bottlenecks, and the desire for greater control over energy costs.

Small scale generating technologies (e.g. solar, wind, hydro or newer technologies) that are connected to the electric power grid are identified as Distributed Grid. DG systems allow customers to produce some or all of the electricity they need. The electricity a customer uses (e.g. for HVAC: consumer electronics, lights) is their electric load. By generating a portion or all of the electricity a customer uses, the customer can effectively reduce their electric load.

In general, DG systems produce power for the buildings which the systems are connected to (e.g. solar panels on a home or business). Renewable DG systems are able to provide power with minimal impact on the environment. However, most renewable DG systems only produce power when their energy source, such as wind or sunlight, is available. Due to the intermittency of the power supply from DG systems, there may be times when the customer needs to receive electricity from the utility company's electric grid. When a DG system produces more power than the customer's load, excess power is sent back to the utility company's electric grid. This reduces the overall load that the utility company needs to supply.

It is proposed that there be established a Borneo-wide distributed grid incorporating solar and wind power plants in Sabah and Sarawak. For that, the existing fossil and hydro power plants are considered as sources. Accordingly, models for different power plants are first reviewed for this proposal. As the distributed grid gets more complex and integrated, better data acquisition and control systems are needed to control load flow and minimise power outages. Power outages usually initiate from a small area and propagate over larger areas causing cascaded power failure. Considering this as well as the distributed power generation from renewables, an Internet based distributed data acquisition and control network is needed.

6.7 ACTION PLAN FOR THE ENERGY SECTOR

Table 6.8 shows the issues and challenges of energy sector, followed by the future needs and proposed recommendation or action plans:

Table 6.8 Issues and challenges of energy sector

NO	ISSUES & CHALLENGES	FUTURE NEEDS (R&D)	PROPOSED RECOMMENDATIONS/ ACTION PLANS
1	• Fuel Purchase • Fuel stockpiling, energy security • IPP • RE projection & achievement • Nuclear power plant • Energy supply surplus & Energy Efficiency	1) Smart fuel purchase – high quality coal 2) Alternative energy source of fuel	• Best practice in sourcing fuel, e.g. coal with good combustion characteristics • Selection of cost effective and efficient alternative energy source
2	Resource Efficient Power generation	1) Awareness and Industrial Practice change 2) Review of design approach 3) Explore Renewable Energy without large scale Ecological Damage – e.g. small hydro 4) Efficient Biomassutilisation for energy source 5) Effective and efficient solar heating for turbines 6) Small scale (and isolated) generation development 7) Energy Storage technology and potential	• All potential generation sectors • Progressing towards sustainability and fuel security

3	• Transmission loss • Balance of System	1) Awareness and Industrial Practice change 2) Review of design approach Equipment selection	• Sourcing efficiency transmission equipment / technologies
4	Energy efficient Distribution	1) Review of distribution method 2) Efficient distribution improvement – software 3) Efficient distribution improvement – hardware	• Developing smart grid • Efficient load distribution – shortest distance from source to user
5	Renewable energy		Maximising benefits to the environment and minimising negative impacts by: 1) Conserving resources by ensuring that Purchasing policy favours environmentally friendly products for building materials, capital goods, food, and consumables. 2) Energy consumption is measured, sources indicated, and measures to decrease overall consumption adopted, while encouraging the use of renewable energy. 3) Greenhouse gas emissions from all sources controlled by the business are measured and procedures are implemented to reduce and offset them as a way to achieve climate neutrality. 4) Practices are implemented which will reduce pollution from noise, light, runoff, erosion, ozone-depleting compounds, and air and soil contaminants

Note: illustrates the final energy demand by sectors in MWhr, namely industrial, 1.8062 cmtransport, agriculture, non-energy, and residential and commercial

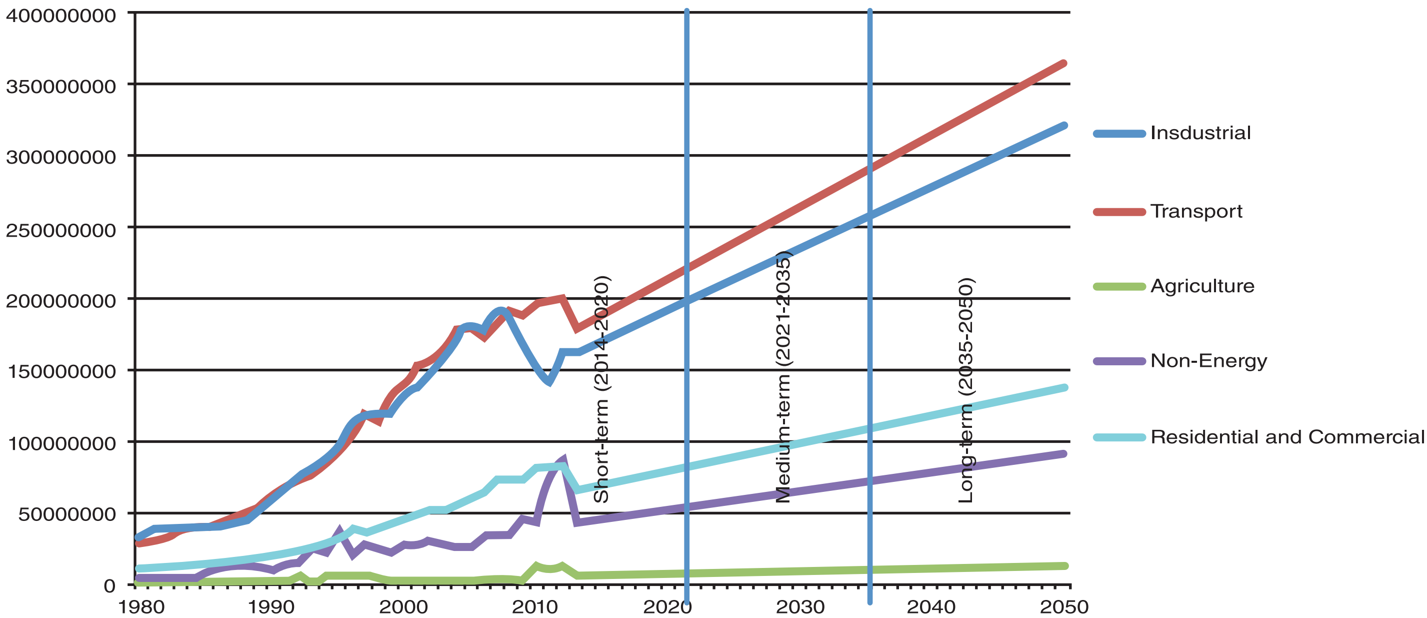


Figure 6.1 Final Energy Demand by Sectors (MWhr)

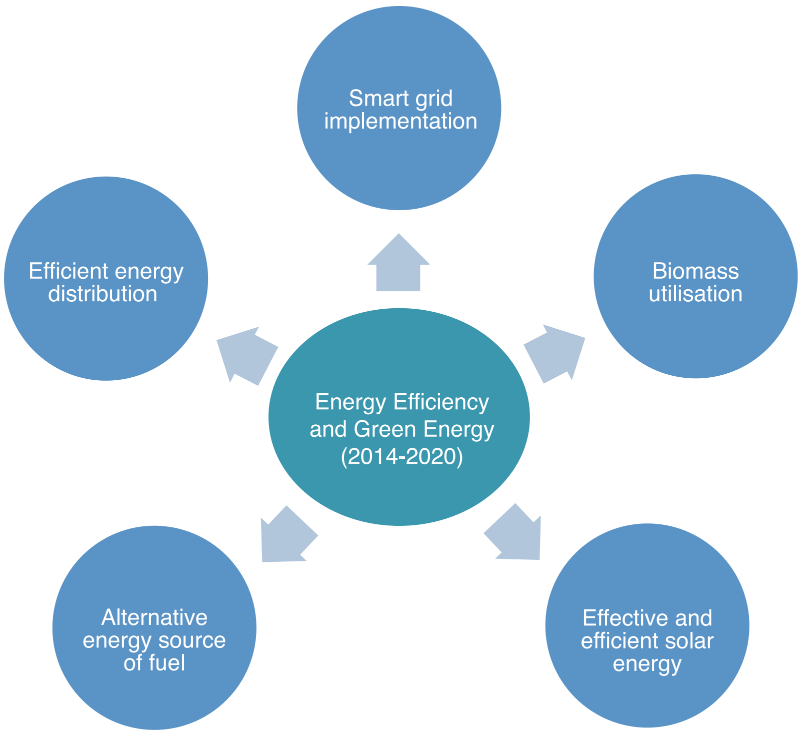


Figure 6.2 Short-term desired scenarios on energy efficiency and green energy technology

6.7.1 SHORT-TERM ACTION PLAN (2014-2020)

The short-term plan is predominantly industry-driven, as many developed countries around the world are expected to achieve these as shown in **Figure 6.2**. The short-term plan is therefore focused on energy efficiency on energy generation and meets the demand of the nation. **Table 6.9** shows some of the action plans for medium term.

Table 6.9 Short-term action plan (2014-2020)

Change dimensions	Actions	Stakeholders	Desired outcomes
R&D	1) Provide support to the domestic industry in developing capacities and expertise to participate effectively as sub-contractors and component suppliers in nuclear power plant projects 2) Information and communication technology integration of smart grid	MOSTI, TNB, scientists, researchers, process engineers, universities, technology investors	1) Supply chains for nuclear construction 2) Distribution grid management of smart grid 3) Smart grids provide an opportunity to link societal, financial, technology and regulatory and policy objectives
Institutional framework and policies	1) Public awareness on nuclear technology and safety 2) Communicate with stakeholders and the public to explain the role of nuclear energy in national energy strategy 3) Governments should communicate with stakeholders and the public to explain the role of nuclear energy in national energy strategy, seeking to build public support through involvement in the policymaking process	MOSTI, PEMANDU, EPU, TNB, private generators	1) Ongoing, as nuclear programmes are launched 2) Build public support through involvement in the policy-making process

Infrastructure	1) Integrates several energy supply and use systems within a given region in an attempt to optimise operation 2) Smart grids to enable the effective integration of significantly higher amounts of variable resources 3) Operate across system boundaries of generation, transmission, distribution and end use 4) Expand pilots on automated demand response especially in service and residential sectors	MITI, universities, colleges	1) Maximum integration of renewable energy resources 2) Effective integration of variable resources to electricity grids 3) Appropriate business models addressing key issues including cost, security and sustainability
Value chain and market development	1) Policies and measures to ensure adequate long-term funding for the management and disposal of radioactive wastes 2) Developing and emerging economies can use smart grids to build from household electrification to community and regional systems	MITI, private investors, startup companies	1) Policies on management and disposal of radioactive wastes 2) Smart grids to build from household electrification

Rural Transformation to Net Neutral Sustainable Energy Community:

There are four main issues faced by rural villages in Malaysia,specifically, urban migration, which stagnates the rural economy of abandoned villages with no rural income generation and insufficient education. These issues can solved by introducing innovative renewable energy technology affordable to economically-depressed grid-less remote areas of the country and generates rural economic activities. Hence, an eco-framework solution to achieve net neutral renewable energy community or zero-energy community must be developed during the short-term (2015-2020), and medium-term (2021-2035) in remote areas off grids of orang *Asli* communities in Semenanjung Malaysia and rural communities of Sabah and Sarawak.

The net neutral renewable energy concept emphasises using all possible cost-effective renewable energy technology and demand-avoidance strategies Malaysia is located in the tropical region where the sky conditions are diffused in nature and low wind speed. Hence, there are challenges in technological and fundamental aspects of renewable energy systems that must be address which can be taken by universities and related research institutions. Besides that, education packages must be developed within the community to achieve desired awareness net neutral concept renewable energy concept provide hands-on training on applications of renewable energy with basic education and societal awareness. The net neutral Sustainable Energy Community concept will create community social activities and development of location-specific cottage industries.

The concept of the neutral community is shown in **Figure 6.3**. It shows the integrated net neutral community formulation. Community Zero Energy behaviour is essential to be achieved and without it no proper formula will be achieved. This can be accomplished by setting community goals for energy and water use. Use policies, Information, education, and incentives and disincentives within the community to achieve desired objectives. During the short term several concept must be developed for remote areas such as the Tasik Chini area in Semenanjung Malaysia and other suitable remote areas of Sabah and Sarawak. Several innovative concepts such as the use of renewable hydrogen production system utilisation fuel cells, as shown in **Figure 6.4**, have to explored, and this will be different from the conventional battery based stand-alone renewable energy systems.

6.7.2 MEDIUM-TERM ACTION PLAN (2021-2035)

The medium term action plan is to further develop and expand the energy industry in the country to embrace new technology for renewable and green energy. Application of new innovative technology is important, especially in producing renewable and green energy. **Table 6.10** shows some of the action plans for the medium term.

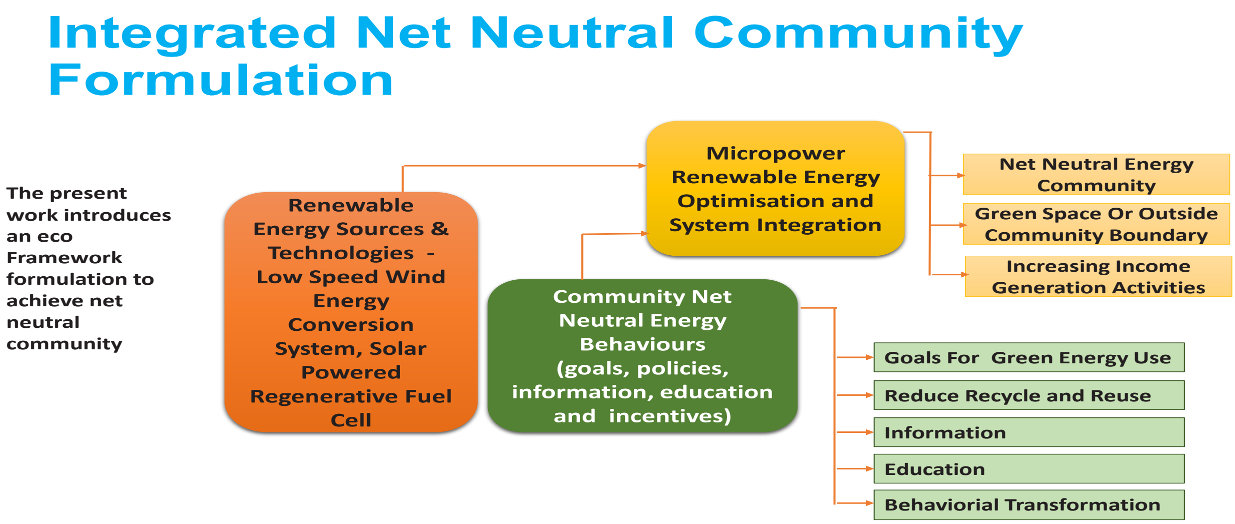


Figure 6.3 Formulation of the integrated net neutral community

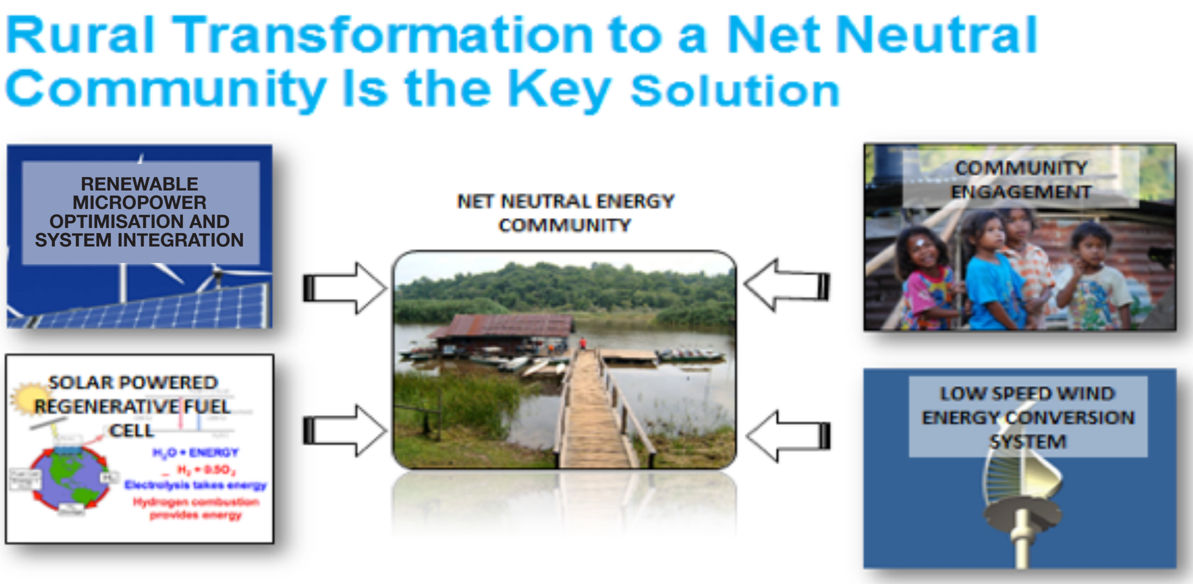


Figure 6.4 Rural transformation into a net neutral community

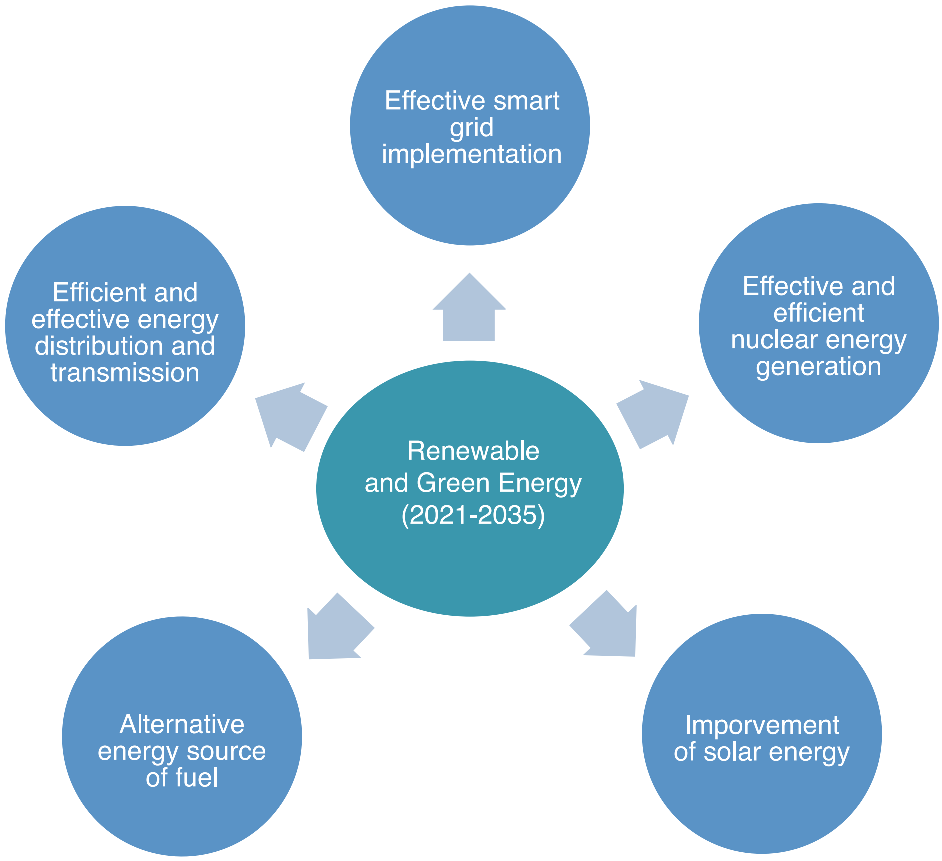


Figure 6.5 Medium-term desired scenarios on energy efficiency and green energy technology

Table 6.10 Medium-term action plan (2021-2035)

Change dimensions	Actions	Stakeholders	Desired outcomes
R&D	1) Replicating standarised designs to the extent possible, continue the evolutionary development of reactor and nuclear fuel designs 2) Determine approaches to address system-wide and cross-sector barriers to enable practical sharing of smart grids	MOSTI, TNB, scientists, researchers, process engineers, universities, technology investors	1) Lessons learned from reference plants will be available 2) Practical sharing of smart grids costs and benefits
Institutional framework and policies	1) Work with the nuclear and electricity industries to ensure a coordinated approach to overcoming obstacles to nuclear development, especially where nuclear energy is being used for the first time 2) Put in place policies and measures to ensure adequate long-term funding for management and disposal of radioactive wastes, decommissioning, establishings the necessary legal and organisational framework for the development, as well as timely implementation of plans for radioactive waste management and disposal 3) Observe international best practice in developing the necessary nuclear energy legislation and regulatory institutions, to ensure that they are both effective and efficient 4) Governments and industry should evaluate priorities and establish protocols, definitions and standards for smart grid	MOSTI, PEMANDU, EPU, TNB, private generators	1) Ongoing, as nuclear programmes are launched 2) Equipment, data transport, interoperability and cyber security, and create plan for standards development

Infrastructure	1) Invest in building up industrial capacities in the nuclear and related engineering industries worldwide to increase the global capability to build nuclear power plants 2) Smart grids can reduce these peaks and optimise system operation 3) Increased levels of demand response for customers from industrial, service and residential sectors 4) Promote adoption of real time energy usage information and pricing 5) Continue expand pilots on automated demand response especially in service and residential sectors	MITI, universities, colleges	1) Significant investment needed by 2015 to build nuclear power plant 2) Optimise system operation of smart grid 3) Coordinating collaboration and responsibilities among electricity system stakeholders 4) Optimum planning, design and operation of distribution system in co-operation with customers
Value chain and market development	1) Build new designs can be reliably built on time and within expected costs, making continuous efforts to reduce construction times and control costs by using standarised designs to the extent possible, refining the construction process and further strengthening supply chains	MITI, private investors, startup companies	1) Ability to build standarised designs on time and to cost by 2020

6.7.3 LONG-TERM ACTION PLAN (2036-2050)

The final term action plan is themed as the next generation technology which suggests futuristic product development for energy supply stability. This action plans are crucial to achieve the final scenario. The only way to be the market leader is by leading technological advancement faster than the competitors. **Table 6.11** presents the action plan for the long term.

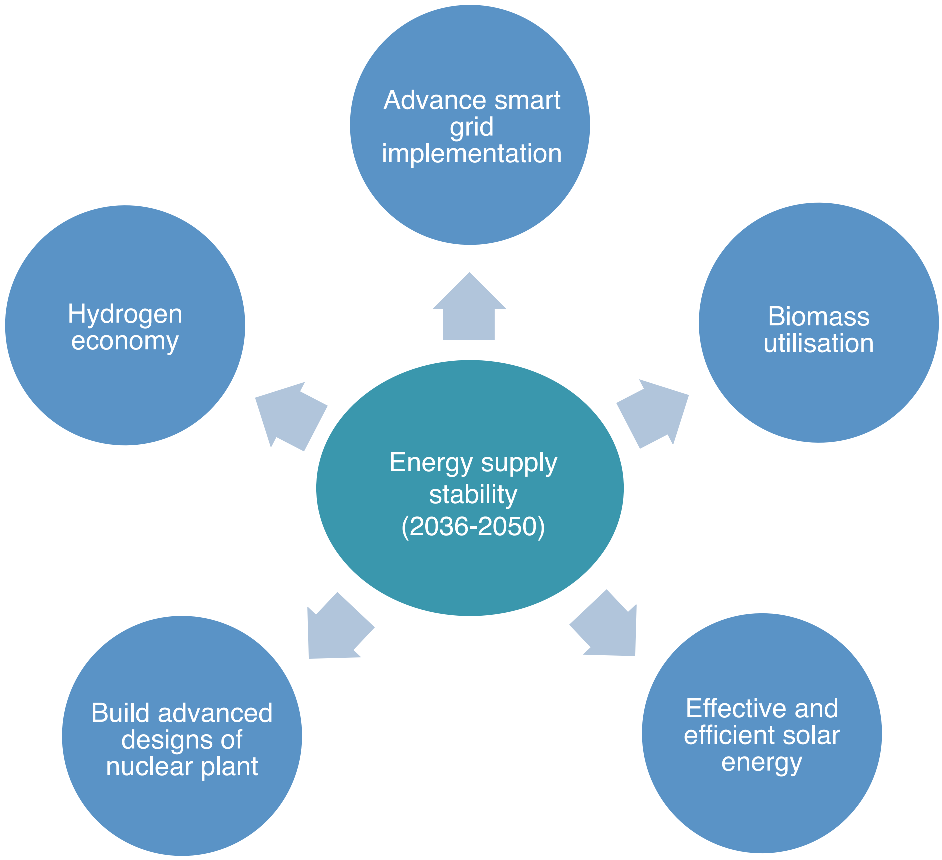


Figure 6.6 Long-term desired scenarios on energy efficiency and green energy technology

Table 6.11 Long-term action plan (2036-2050)

Change dimensions	Actions	Stakeholders	Desired outcomes
R&D	1) Develop where necessary and implement plans for the long-term management and disposal of all types of radioactive wastes, in particular for the construction and operation of geological repositories for spent fuel and high-level waste 2) Expand uranium production and the capacity of nuclear fuel cycle facilities in line with the growth of nuclear generating capacity, including the deployment of more efficient advanced technologies where available 3) Develop an evolutionary approach to regulation for changing the generation landscape from existing and conventional assets	MOSTI, TNB, scientists, researchers, process engineers, universities, technology investors	1) To be in operation by 2020 2) Major capacity expansion needed by 2040-2050 and beyond 3) Variable and distributed approaches for changing the generation landscape
Institutional framework and policies	1) Ensure that the system of nuclear energy-related legislation and regulatory oversight provides an appropriate balance between protecting the public and the environment while providing the certainty and timeliness required for investment decisions, and make reforms if required. 2) Expand collaboration in the development of international standards to reduce costs and accelerate innovation for smart grid	MOSTI, PEMANDU, EPU, TNB, private generators	1) Ongoing, as nuclear programmes are launched 2) Globally accepted standards for smart grid

Infrastructure	1) Fully establish the latest nuclear power plant designs by constructing reference plants in a few countries around the world, to refine the basic design and any regional variants, and build up global supply chains and capacities 2) Continue to deploy smart grids on the transmission system 3) Continue expand pilots on automated demand response especially in service and residential sectors	MITI, universities, colleges	1) New designs now under construction will be in operation by 2015 2) Increase visibility of operation parameters and reliability
Value chain and market development	1) Continue building new designs that can be reliably built on time and within expected costs; making continuous efforts to reduce construction times as well as control costs by using advanced designs to the extent possible, refining the construction process and further strengthening supply chains 2) A broad range of product and service providers who have not worked together in the past will have to collaborate in smart grids deployment	MITI, private investors, startup companies	1) Ability to build advanced designs on time and to cost by 2050 2) Product and service providers collaborate in smart grids deployment

Transition towards the Hydrogen Economy: Transition towards the hydrogen economy to substitute the current hydrocarbon economy will begin at the end of the long term (2036-2050). Hydrogen acts as an energy carrier and is environmentally cleaner source of energy to end-users, particularly in transportation, residential and commercial sectors applications, without release of pollutants (such as particulate matter) or carbon dioxide at the point of end use as shown in **Figure 6.7**. In the short-term (2015- 2020) and medium-term (2021 – 2035) demonstration projects, renewable hydrogen production and fuel cell should be funded. By which, the concept of renewable hydrogen and regenerative fuel cells for rural electrification should be introduced and the competiveness of this concept compared to conventional the renewable energy hybrid battery system.

6.8 CONCLUSION

In Malaysia, EE is given high priority within these key sectors: Independent Power Producers, industrial manufacturing, building design, transportation, and residential. Several existing programmes and projects have been initiated to address industrial energy usage to resolve development barriers and demonstrate the effectiveness of EE applications. Electricity supply service in Malaysia is vertically integrated with three main electricity utilities or Independent Power Producers (IPP) in Peninsular, Sabah and Sarawak - operating generation, transmission, distribution and supply activities. In addition, there are 18 investor-owned independent power producers supplying power to these utilities. Several mini-utilities generate electricity or purchase power from the main utilities for their own use with excess power supply sold to consumers within certain dedicated areas.

The Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP) is a forerunner in building capacity to create energy saving technologies and financial incentives; the project conducts audits and engineering services to plant operators, while promoting energy monitoring and better design aspects. The activities under the MIEEIP are implemented for eight industrial sectors: cement, ceramic, food, glass, iron & steel, pulp & paper, rubber and wood.

Energy efficiency in buildings means using less energy for heating, cooling and lighting. For that, it also means buying energy-saving appliances and equipment for use in a building. Integrating EE features into the architecture and conducting energy audits ensures that mechanical systems work together effectively and efficiently. The transportation sector is pivotal in the growth and functioning of the Malaysian economy, but it also consumes the most energy. To offset scarce and expensive petroleum fuels, viable alternative fuels (natural gas and bio-fuels) can provide huge savings for vehicles, especially when integrated with improvements in public transportation.

Consumption of electricity in the residential sector is particularly high and, together with the commercial sector, represents almost 28% of the total demand for the country. Basic energy is used for cooling and lighting our homes, to operate appliances and machines, and water heating as well as for cooking. Placement, design, and construction materials used does affect the energy efficiency of homes. Heat recovery and solar energy technologies are some options that are available to provide solutions for homeowners (GreenTech Malaysia 2013).

Malaysia has an abundance of renewable energy, making alternative energy an attractive option to consider. The market for renewable energy solutions is expected to boom in the near future. By implementing feasible projects now, local manufacturers would be wise to pay attention to this growing market and take advantage of business opportunities and lower energy costs. Renewable Energy (RE) is energy obtained from natural resources such as wind, solar, rain and tides, which are naturally replenished. RE resources are reliable, efficient and competitive as compared to conventional technology. Over the past few decades, increased use of RE has resulted in a substantial improvement in RE technologies. Industrial and institutional equipment - biomass boilers, photovoltaic panels, combined heat and power plants, and solar water heaters - can provide immediate benefits to many Malaysian businesses.

A roadmap for the short-term action plan (2015-2020) has been developed. The short-term plan is predominantly industry-driven, as many developed countries around the world are expected to achieve the following action plans on energy efficiency and green energy such smart grid implementation, Net neutral renewable energy sustainable system, Effective and efficient solar energy, Alternative energy source of fuel and Efficient energy distribution.

The roadmap for the medium Medium-term action plan (2021-2035) has been developed with the objective of to further expanding the energy industry in the country to embrace new technology for renewable and green energy. Application of new innovative technology is important, especially in producing renewable and green energy. Certain action plans of the medium term include effective smart grid implementation, effective and efficient nuclear energy generation, improvement of solar energy and alternative energy source of fuel, including efficient and effective energy distribution and transmission.

The long-term action plan (2036-2050) is themed as the next generation technology which suggests futuristic product development for energy supply stability. This action plan is crucial to achieve the final scenario. The only way to be the market leader is by leading technological advancement faster than the competitor. The action plans for the long term include advanced smart grid implementation, carbon neutral sustainable community, effective and efficient solar energy build advanced designs of nuclear plant and finally transition to the Hydrogen economy beyond 2050.

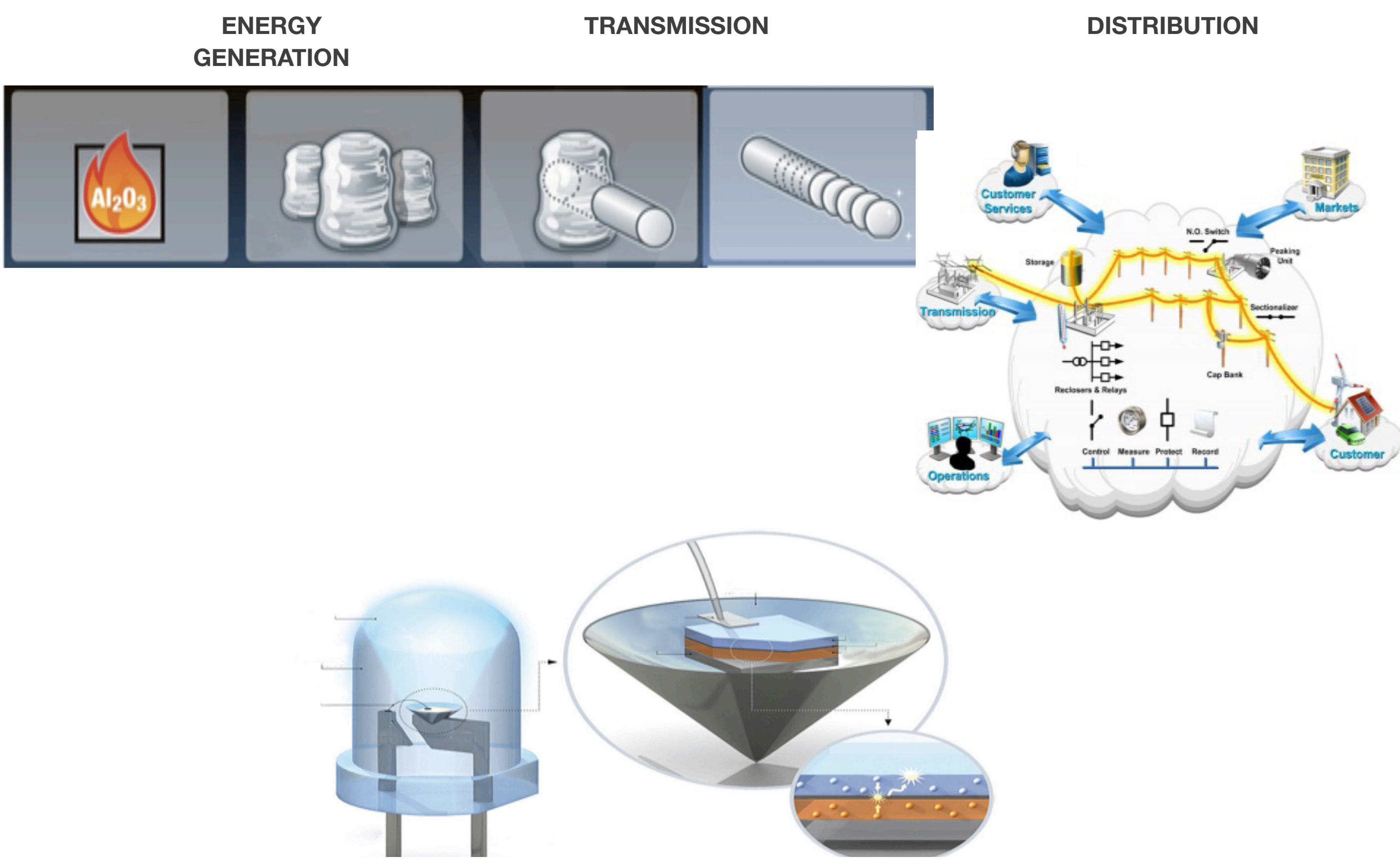


Figure 6.7 Transition to a full hydrogen economy beyond 2050 for Malaysia

CHAPTER 7

SOLAR AS AN EFFICIENT RENEWABLE ENERGY - BASELINE STUDY: GLOBAL DRIVERS,TECHNOLOGY OVERVIEW, CASE STUDIES, MARKET TREND, MALAYSIA'S CURRENT STATUS, DESIRED OUTCOMES

Solar energy is an environment-friendly energy resource with huge potential for fulfilling the energy demands of mankind. It can play a substantial role towards achieving a sustainable low-hydrocarbon future. This is especially true for Malaysia, given her favourable natural geographical settings that can be tapped to drive a vibrant solar energy industry. The applications of solar energy for Malaysia's residential, commercial and industrial sectors are potentially huge.

The solar energy applications can be classified into 2 broad technological categories, namely solar photovoltaic (PV) technology and solar thermal technology. Solar PV technology converts sunlight into electricity using a specific type of semiconductor device known as a solar PV cell. Solar PV cells are primarily used in grid-connected PV systems to power residential and commercial appliances, including lighting and air-conditioning. When solar PV cells are fitted in a stand alone system equipped with batteries, they can be used in remote regions where there is no grid electricity. Solar PV panels can be ground-mounted, installed on building rooftops or designed into building materials at the point of manufacturing. The other category of solar energy application is the solar thermal technology, in which solar radiation is converted into useful heat for various applications such as industrial processes, water and air heating, and drying.

7.1 GLOBAL DRIVERS

The global drivers of the growth and demand of solar energy are worldwide concerns, which are as follows:

i) energy security and fossil fuel price

ii) international pacts and public policies

iii) dramatic reduction of technology costs

iv) public sentiment

7.1.1 ENERGY SECURITY AND FOSSIL FUEL PRICE INCREASE

Following the global energy crisis of the 70's and early 2000's, governments around the world have demonstrated increasing concern about their energy security, which is intricately connected to the delicate political stability of a few oil-rich middle-eastern countries (**Figure 7.1**). Only 8 countries in the world possess 81% of global crude oil reserves; 6 countries have 70% of all natural gas reserves; and 8 countries have 89% of all coal reserves. The US imports 20% of its energy needs, while more than half of Asia, Africa and Latin America import over half of all their energy needs.

With such heavy reliance on external sources, shortages in supplies could cause destabilisation of national economies. To ameliorate these dangers, many governments have implemented strategies to increase the proportions of renewable energy resources in their energy-mix, which would simultaneously stimulate local economies and reduce energy costs and national debts.

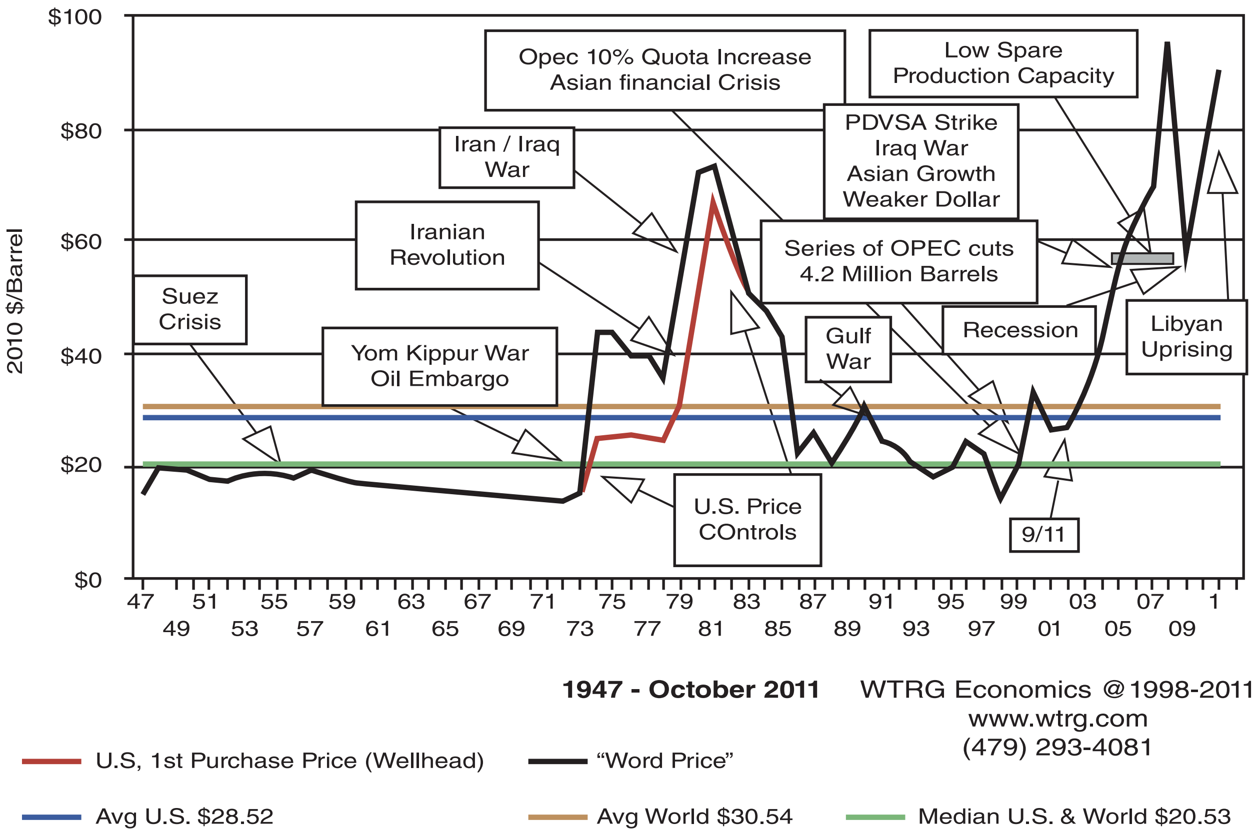


Figure 7.1 Real (2010 US dollar) and nominal crude oil prices, with peaks seen during oil crisis of 1970's and 2000's

Source: www.wtrg.com

7.1.2 INTERNATIONAL PACTS AND PUBLIC POLICIES

Enforcement of public policies supportive of renewable energies is one of the most effective drivers of solar power. Driven by environmental concerns, many governments have implemented policies to encourage investments in renewable energies, in addition to committing to international pacts to reduce carbon footprint.

One such pact is the EU Renewable Directive, which mandates levels of renewable energy use within the European Union. Published in 2009, the directive requires its 28 member States to produce a pre-agreed national proportion of energy consumption from renewables such that the EU as a whole shall obtain at least 20% of total energy consumption from renewables by the year 2020 (**Table 7.1**).

Table 7.1 EU national overall targets for the share of energy from renewable sources in gross final consumption of energy in 2020

	2009	2009	Objective 2020 de la directive 2009/28/CE **Objective 2020 from the 2009/28/EC Directive**
Sweden	47.7%	46.9%	49.0%
Latvia	35.5%	34.3%	40.0%
Finland	30.7%	33.6%	38.0%
Austria	30.2%	30.7%	34.0%
Portugal	24.7%	24.7%	31.0%
Estonia	23.4%	24.1%	25.0%
Denmark	19.2%	23.0%	30.0%
Slovenia	19.7%	21.7%	25.0%
Romania	22.9%	21.4%	24.0%
Lithuania	20.8%	21.1%	23.0%
Spain	12.9%	14.1%	20.0%
Bulgaria	11.6%	12.9%	16.0%
France	11.7%	12.4%	23.0%
Slovakia	10.7%	11.4%	14.0%
Germany	9.3%	10.7%	18.0%
Poland	9.0%	9.9%	15.0%
Czech Republic	8.5%	9.7%	13.0%
Greece	8.0%	9.1%	18.0%
Italy	7.7%	8.5%	17.0%
Hungary	8.5%	8.5%	13.0%
Ireland	5.1%	5.9%	16.0%
Cyprus	4.9%	5.5%	13.0%
Belgium	4.7%	5.4%	13.0%
Netherlands	4.0%	3.8%	14.0%
United Kingdom	3.0%	3.3%	15.0%
Luxembourg	2.6%	2.6%	11.0%
Malta	0.2%	0.3%	10.0%
European Union (27 countries)	**11.5%**	**12.4%**	**20.0%**

Source: www.erec.org

7.1.3 DRAMATIC COST REDUCTION OF SILICON PVCELLS

Driven by escalating demands and continuously improved technologies, the cost of silicon PV cells has reduced dramatically over the last four decades (**Figure 7.2**). Swanson's Law, named after the founder of solar panel manufacturer Sun Power Corporation, is an observation that the price of solar PV modules tends to drop 20% for every doubling of cumulative shipped volume. The crystalline silicon PV cell which dominates 90% of the market now costs ~USD 0.70/watt, which is less than 1% of what it was in 1977.

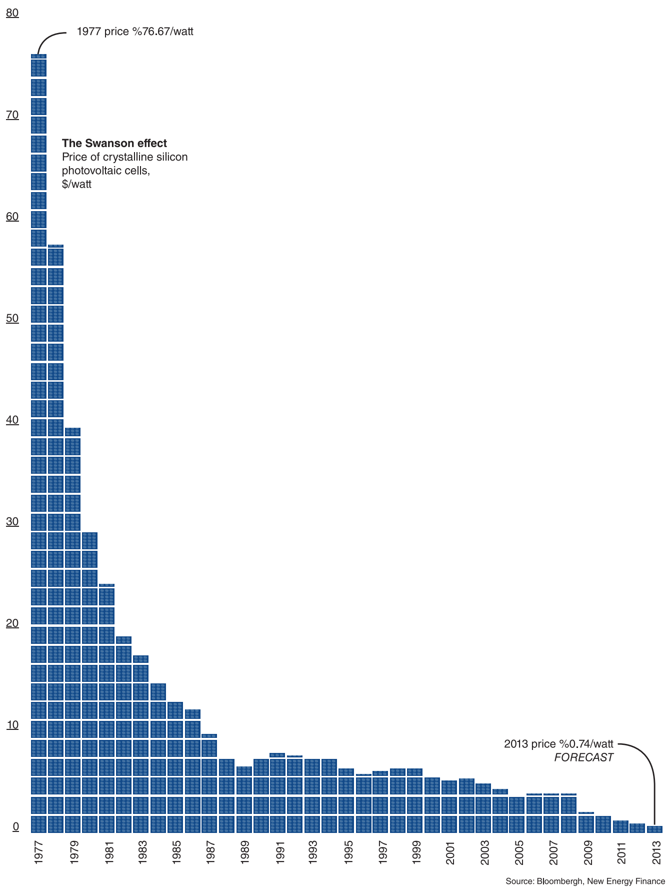


Figure 7.2 The dramatic price reduction of silicon solar PV cells

Source: Bloomberg New Energy Finance

7.1.4 PUBLIC SENTIMENT

Pressures of escalating oil prices have led to the increase of public support towards renewable energies. In the European Union, majorities in all 27 states support the increasing the share of renewable energies to 20% by the year 2020. In the US, an overwhelming 9 in 10 persons surveyed see it as important to invest in renewable energy, and 8 in 10 support tax incentives for this purpose.

Moreover, the higher costs of renewable energies do not seem to be a deterrence of public support. In 2011, researchers at Harvard and Yale found that the average US citizen was willing to pay $162 a year more to support a national policy requiring 80% clean energy by 2035. Added to that, there are also supportive projections that investments in alternative energy will pay off economically in the long run.

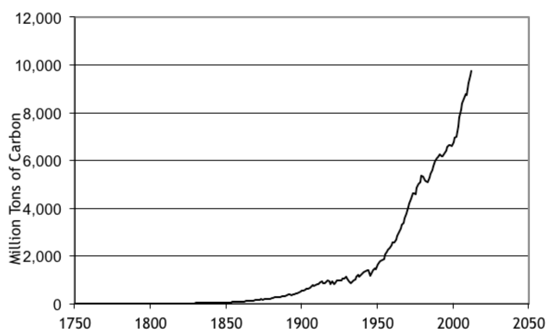


Figure 7.3 Global CO2 emissions from fossil fuel

Source: www.earthpolicy.org

Public support towards renewable energies is also driven by concerns of the environmental impact of fossil fuels. **Figure 7.3** shows carbon dioxide (CO_2) emissions from fossil fuels, which are growing exponentially despite worldwide agreements by governments on emission limits. After a short dip due to the global financial crisis in 2009, emissions rebounded in 2010 and have since grown 2.6% every year, hitting an all-time high of 9.7 billion tons in 2012. Scientists warn of dire consequences, including greenhouse effect and global climate change.

7.2 SOLAR ENERGY TECHNOLOGY OVERVIEW

The energy resources of the world include solar radiation, geothermal, wave and tidal, including nuclear energy. These can be classified as shown in **Figure 7.4**. Solar radiation energy resource can be further divided into direct solar energy, stored solar energy (renewable hydrocarbon such as biogas and biomass; and non-renewable hydrocarbon such as shale, petroleum, natural gas and coal) and indirect solar energy (wind and hydropower).

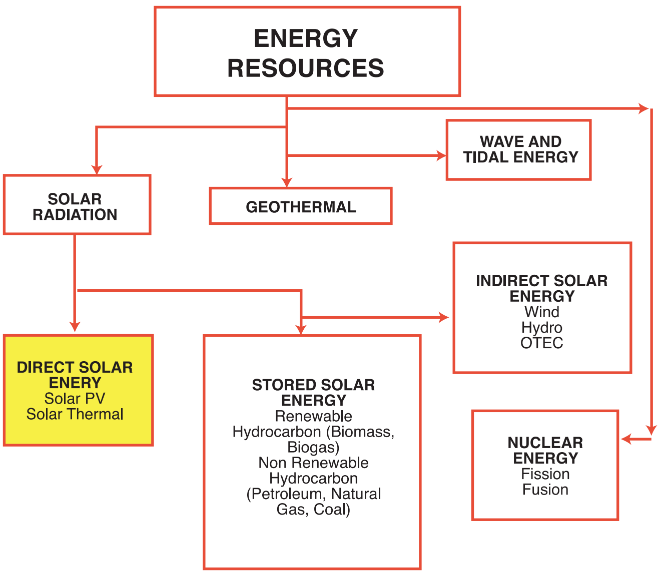


Figure 7.4 Classification of the world's energy resources

Direct solar energy technology can be divided into:

(a) solar photovoltaic (PV) technology — production of electricity by solar PV cells for stand alone and grid-connected applications; and (b) solar thermal technology — production of hot air or water for various applications such as drying, cooling, water heating and industrial processes.

7.2.1 SOLAR PHOTOVOLTAIC (PV) TECHNOLOGY

A solar photovoltaic (PV) cell (**Figure 7.5**) is made of semiconductor materials. When exposed to light, the valence electrons of the semiconductor are excited and freed, causing electrical current. The two major types of solar PV cells are crystalline silicon and thin-films, which differ from each other in terms of light absorption ability, energy conversion efficiency, manufacturing technology, and production costs. Solar PV cells are silent and clean in operation, highly reliable, have low maintenance, and extremely robust with expected lifetime of at least 20 to 30 years. They are also very modular, and thus can be adapted for many locations and applications.

Figure 7.5 A crystalline silicon solar PV cell

7.2.1.1 CRYSTALLINE SILICON PV

Crystalline silicon solar cells can be divided into two types, namely mono-crystalline and poly-crystalline solar cells. The following describes these solar cells:

a. *Mono-crystalline solar cell*: Manufactured by sawing wafers from a very pure single and continuous cylindrical crystal of silicon with zero defect and impurities. Most efficient (~15% – 20%) and most expensive;

b. *Poly-crystalline solar cell*: Manufactured by sawing wafers from an ingot of melted and recrystallised silicon (cast Si) of multiple small crystals. Less efficient (12%–15% typical modules), but less expensive than mono-crystalline, and its manufacturing process is simpler.

7.2.1.2 THIN-FILM SOLAR CELL

A thin-film solar cell (TFSC), also known as thin-film PV cell (TFPV), is a solar cell that is made by depositing one or more thin layers of PV material on a substrate, usually coated glass, metal or plastic. The thickness range of such a layer varies from a few nanometres to tens of micrometres. A thin-film solar cell is more flexible, cheaper and easier to manufacture compared to crystalline silicon solar cell, hence useful for small-scale applications such as calculators. Thin-film solar cells are usually categorised based on the PV material used:

a. *Amorphous silicon* (a-Si) and other *thin-film silicon* (TF-Si): Manufactured as a thin film of deposited disordered Si on glass or metal (flexible) substrates;

b. *Cadmium telluride* (CdTe): An efficient light absorbing material;

c. *Copper Indium Gallium Selenide* (CIS or CIGS), *Copper Indium Gallium Diselenide* (CuInSe2): The highest efficiency thin-film cell/module (12% to 13%).

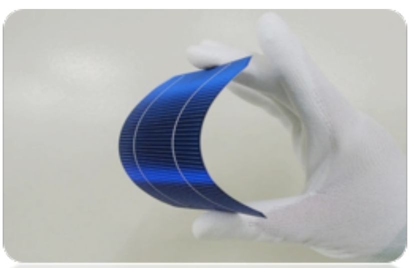


Figure 7.6 A thin-film solar cell

7.2.1.3 DYE-SENSITISED SOLAR CELL AND OTHER ORGANIC SOLAR CELLS

A dye-sensitised solar cell (DSSC) is a low-cost thin-film solar cell based on a semiconductor formed between a photo-sensitised anode and an electrolyte. An organic solar cell makes use of organic polymers for light absorption and charge transport. Thin film of organic semiconductor made from polymer and polyethylene are still in the early stage of development. Organic solar cells are potentially the least expensive solar cell. However, its efficiency is currently very low at less than 3%.

7.2.1.4 NEXT GENERATION HIGH-PERFORMANCE GRAPHENE-BASED SOLAR CELLS

Due to its varied interesting properties, graphene and its derivatives are a promising candidate material for producing next generation of high-performance solar cells. Many studies indicate that the morphological, electrical, optical and mechanical properties of carbon nano-materials can enhance the energy-conversion performance of solar cells.

For this reason, interest in graphene-based solar cells has been growing in the past few years. Among all the types of solar cells, the graphene-based dye-sensitised solar cell (**Figure 7.7**) potentially offers a successful solution to extend the solar absorption range to longer wavelengths, with the high conductivity of graphene facilitating electron transport in the solar cell. **Table 7.2** summarises some research studies focusing on graphene-based solar PV cells.

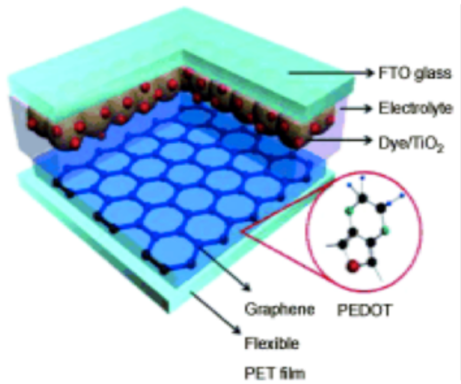


Figure 7.7 A dye-sensitised solar cell fabricated with graphene-oxide

Source: Y.L. Kun Seok Lee

Table 7.2 Graphene-based solar cells and studied structures

Solar cell type	Solar cell structure
Graphene polymer solar cell	ITO/GO/P3HT:PCBM/LiF/Al
	ITO/ZnO/C_{60}-SAM/P3HT:PCBM/GO/Ag
	Multilayer graphene (MLG)/PEDOT:PSS/ P3HT:PCBM/Ca/Al
	ITO/GO/NiO_x/P3HT:PCBM/LiF/Al
Graphene-based dye-sensitised solar cells	TiO_2+GO
	Counter electrode of ITO/[PDDA@ERGO] in low volatility electrolyte
	Graphene/SiO_2 composite cathode in I_3^-/I^- redox electrolyte
	Graphene nanoplatelets (GP) cathode in $[Co(bpy)_3]^{3+/2+}$ redox electrolyte
Graphene quantum dot solar cells	ITO/PEDOT:PSS/P3HT:Graphene quantum dots (GQDs)/Al
	CoS/graphene sheet (CoS/GS) electrode
	TiO_2-NA and CdS/TiO_2-NA loading with graphene quantum dot (GQDs)
	Quantum dot dye-sensitised solar cells (QDSSCs) based on TiO_2 film photoanode with graphene
Graphene in tandem solar cells	ITO/PEDOT:PSS/P3HT:PCBM/MoO_3 coated graphene/P3HT:PCBM/LiF/Al
	P3HT:PCBM/GO:PEDOT/P3HT:PCBM/Al/ Ca
	ITO/GO:SWCNTs/P3HT:PCBM/ ZnO+GO:SWCNTs/P3HT:PCBM/Ca/Al

7.2.1.5 STAND-ALONE PV SYSTEM

In many PV systems, the generated electricity will not be used as it is produced but may be required during the night or during cloudy weather conditions. A stand-alone PV system as shown in **Figure 7.8** consists of a PV array which is built up from a number of PV panels to make up the peak power capacity; a charger-controller for controlling the charging and discharging of battery; and a battery bank for storing the generated electrical energy for later use. Storing electrical energy makes the stand alone PV system a reliable source of power day and night. PV systems with battery storage are being used all over the world to power lights, sensors, recording equipment, switches, telephones, televisions, and power tools.

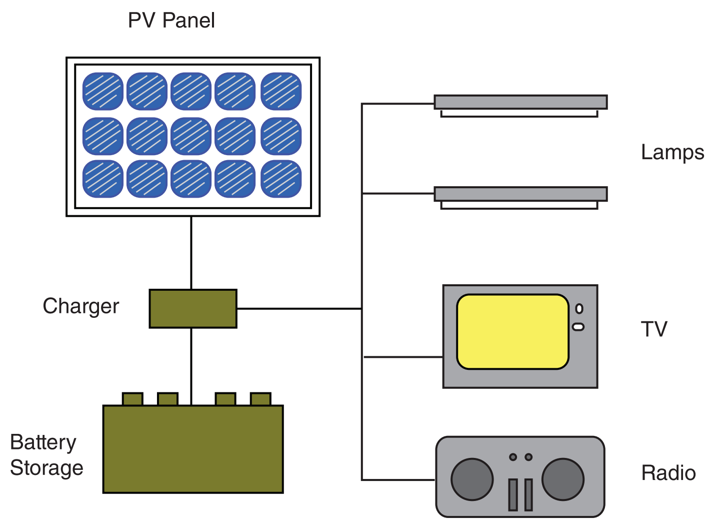


Figure 7.8 A stand-alone PV system

The batteries are direct-current devices and are directly compatible only with dc loads. Besides storing electrical energy, the batteries can also serve as a power conditioner to the loads. This allows the PV array to operate closer to its optimum power output. Most batteries must be protected from overcharge and excessive discharge, which can cause electrolyte loss and can plate damage. Protection is usually achieved using a charge controller, which also maintains system voltage. Most charge controllers also have a mechanism that prevents current from flowing from the battery back into the array at night.

7.2.1.6 HYBRID PV SYSTEM

A hybrid PV system has the components of a standalone PV system in addition to power generating system(s). Normally, the additional power generating system is a diesel generator. A hybrid PV system is capable of supplying power without interruption because the power generator can be programmed to operate at regular intervals so as to maintain the battery bank being fully charged. Hybrid PV systems are essential power source in remote areas beyond the reach of power grid.

7.2.1.7 GRID-CONNECTED PV SYSTEM

In a grid-connected PV system (**Figure 7.9**), the electricity generated can be used on site or fed (sold) through a meter into the utility grid. Net metering is an important aspect in a grid-connected PV system, enabling the system operator to buy and sell electricity. When the operator requires more electricity than the PV array is generating, the need can be automatically met by power drawn from the utility grid. When less electricity is required, the excess power generated by the PV is fed (or sold at a certain tariff, known as feed-in-tariff) back to the utility. Used this way, the utility backs up the PV like batteries do in standalone systems, thus eliminating the need for a battery bank that adds costs of the system. At the end of the billing period, a credit for electricity sold gets deducted from charges for electricity purchased.

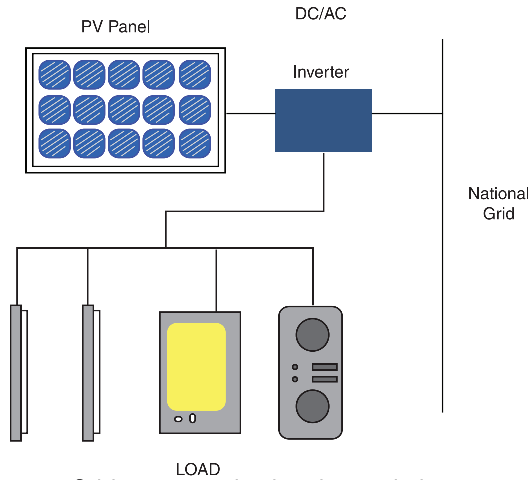


Figure 7.9 Grid-connected solar photovoltaic system

7.2.2 SOLAR THERMAL TECHNOLOGY

In a solar thermal application (**Figure 7.10**), heat from solar radiation is used for various applications such as drying, cooling, air and water heating. A solar water heater for domestic water heating may not be an essential item in a typical Malaysian household, but it has many industrial applications in which heated water is needed such as in hotels, hospitals, and for industrial processes in the food and textile industries.

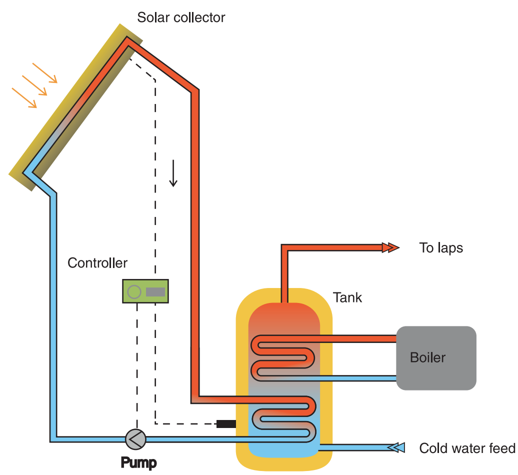


Figure 7.10 Solar thermal water heating system uses the thermal radiation from the sun to heat water

Source: www.solarage.co.uk

The most important component of solar thermal technology is a solar thermal collector. A solar thermal collector is designed to collect heat by absorbing sunlight. Solar thermal collectors fall into two general categories, namely non-concentrating and concentrating.

In the non-concentrating type, the collector area (i.e. the area that intercepts the solar radiation) is the same as the absorber area (i.e. the area absorbing the radiation). In these types the whole solar panel absorbs the light. The concentrating type of thermal collector is composed of mirrors or lenses to concentrate sunlight collected from a large area onto a small area, in which the heat is converted to electricity.

7.2.2.1 SOLAR WATER HEATER

In a solar water heater, the flat-plate and evacuated tube solar collectors are used to collect heat for water heating. They consist of a dark flat-plate absorber of solar energy; a transparent cover that allows solar energy to pass through but reduces heat loss; a heat-transport fluid flowing through tubes to remove heat from the absorber; and a heat insulating backing. The absorber consists of a thin absorber sheet (of thermally stable polymers, aluminum, steel or copper, to which a black or selective coating is applied) backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover. Fluid is circulated through the tubing to transfer heat from the absorber to an insulated water tank. This may be achieved directly or through a heat exchanger. Some fabricates have a completely flooded absorber consisting of two sheets of metal stamped to produce a circulation zone. Because the heat exchange area is greater, they may be marginally more efficient than traditional absorbers.

An alternative to metal collectors is new polymer flat-plate collectors. These may be wholly polymer, or they may include metal plates in front of freeze-tolerant water channels made of silicon rubber. Polymers, being flexible and therefore freeze-tolerant, are able to contain plain water instead of antifreeze. Therefore, they may be plumbed directly into existing water tanks instead of needing to use heat exchangers that lower efficiency. By dispensing with a heat exchanger in these flat plate panel, temperatures need not be quite so high for the circulation system to be switched on, so such direct circulation panels, whether polymer or otherwise, can be more efficient, particularly at low light levels. However, polymer collectors suffer from overheating when insulated, as stagnation temperatures can exceed the melting point of the polymer. For instance, the melting point of polypropylene is 160°C, whereas the stagnation temperature of insulated thermal collectors may exceed 180°C if control strategies are not used.

The evacuated tube collectors have multiple evacuated borosilicate glass tubes which heat up solar absorbers, and ultimately, solar working fluid (water or an antifreeze mix—typically propylene glycol) in order to heat domestic hot water, or for hydronic space heating. The vacuum within the evacuated tubes reduces convection and conduction heat losses, enabling them to reach considerably higher temperatures than most flat-plate collectors. There are two types of tube collectors which are distinguished by their heat transfer method: the older type pumps a heat transfer fluid (water or antifreeze) through a U-shaped copper tube in each of the glass collector tubes.

7.2.2.2 SOLAR AIR HEATER

A solar air heater (**Figure 7.11**) uses solar panels to warm air, which is then conveyed into a room or drying chamber. Air is heated in a collector and either transferred directly to the interior space or to a storage medium, such as a rock bin. The basic components of a solar air heater system include solar collector panels, a duct system and diffusers. The systems can operate with or without a fan. Without a fan, the air is distributed through natural ventilation.

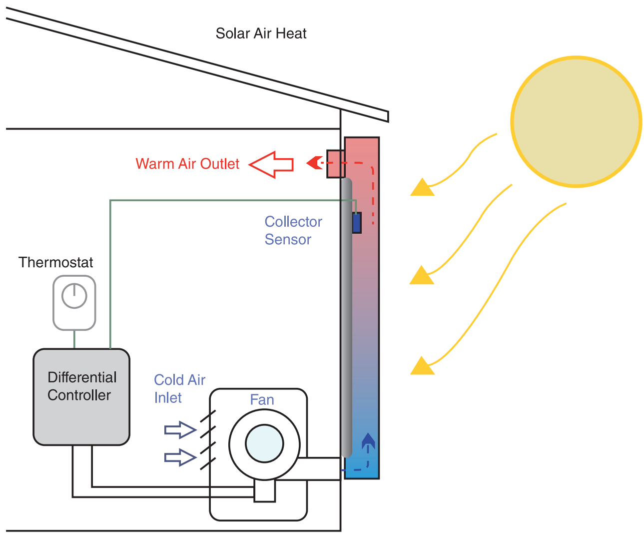


Figure 7.11 A solar air collects the sun's thermal energy to warm the air inside a building

7.2.2.3 PHOTOVOLTAIC THERMAL COLLECTORS

Photovoltaic thermal collectors (PVT) are solar thermal collectors that use PV cells as an integral part of the absorber plate. The system simultaneously generates both thermal and electrical energy. The number of the PV cells in the system can be adjusted according to the local load demands.

In a conventional solar thermal system, an external electrical energy is required to circulate the working fluid through the system. With a suitable PVT design, one can produce a self-sufficient solar collector system that requires no external electrical energy to run. The different options in the development in PVT systems have been categorised by the heat transfer fluid used, such as air, water, or refrigerant.

7.2.2.4 SOLAR CONCENTRATING TECHNOLOGIES

Concentrated solar power (also called concentrating solar power, concentrated solar thermal, and CSP) systems use mirrors or lenses with solar tracking systems to concentrate a large area of sunlight onto a small area. Electrical power is produced when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator. The solar concentrators used in CSP systems can often also be used to provide industrial process heating or cooling, such as in solar air-conditioning.

Concentrating technologies exist in four common forms: parabolic-trough, dish Stirlings, concentrating linear Fresnel reflector, and solar power tower. Although simple, these solar concentrators are considerably far from their theoretical maximum concentrating capabilities. For example, the parabolic-trough concentration gives about one-third of the theoretical maximum for the design acceptance angle. The theoretical maximum may be further approached using elaborate concentrators based on non-imaging optics.

Different types of concentrators produce different peak temperatures and correspondingly varying thermodynamic efficiencies, due to differences in the way that they track the sun and focus light. However, CSP technologies utilise the direct component of the solar radiation only, and are unsuitable for Malaysia due to the diffused nature of solar radiation in the tropics.

7.3 CASE STUDIES

7.3.1 EFFECTIVE FEED-IN-TARIFFS BOOST GROWTH OF SOLAR POWER IN GERMANY

Germany is one of the world's biggest solar PV installer, with an operating capacity of 34.791 GW at the end of August 2013. Germany's new solar PV installations increased by about 7.6 GW in 2012, and solar PV provided 18 TWh of electricity in 2011, which is about 3% of total electricity. Large PV power plants in Germany include Senftenberg Solar Park, Finsterwalde Solar Park, Lieberose Photovoltaic Solar Park, Strasskirchen Solar Park, Waldpolenz Solar Park, and Köthen Solar Park.

Figure 7.12 The 78 MW Phase 1 of the Senftenberg Solar Park in Germany generates power for 25,000 households

The German government has set a target of 66 GW of installed solar PV capacity by 2030, to be reached with an annual increase of 2.5 to 3.5 GW,and a goal of 80% of electricity from renewable sources by 2050. Solar power in Germany has been growing dramatically due to the country's feed-in-tariffs for renewable energies, which were introduced by the German Renewable Energy Act. The Act has helped to push the prices of PV systems down by more than 50% in five years since 2006 (**Figure 7.13**). This dramatic cost reduction results in an exponential increase of solar power installations in Germany over the last 20 years, with a doubling time of 1.5 years, as shown in **Figure 7.14** and **Figure 7.15**.

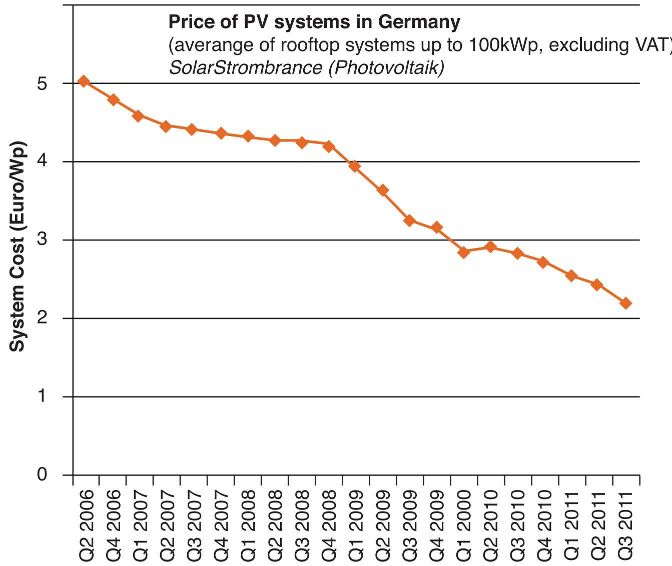


Figure 7.13 Dramatic price reductions of PV systems in Germany

Source: BSW-Solar

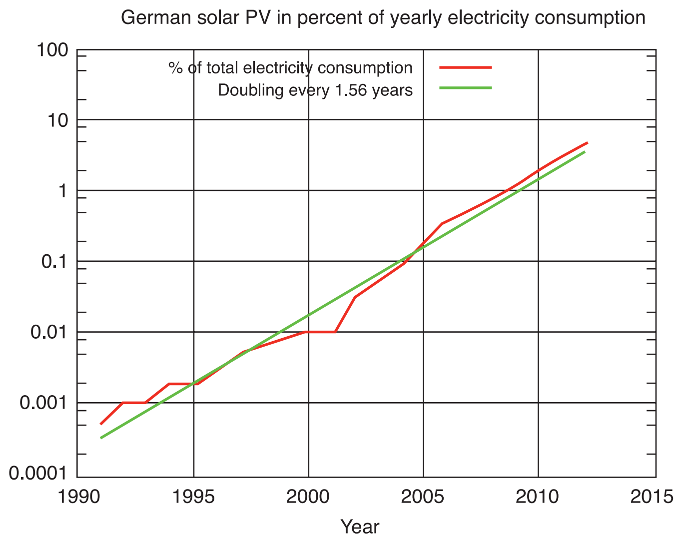


Figure 7.14 The percentage proportion of solar-generated power out of total electricity consumption in Germany

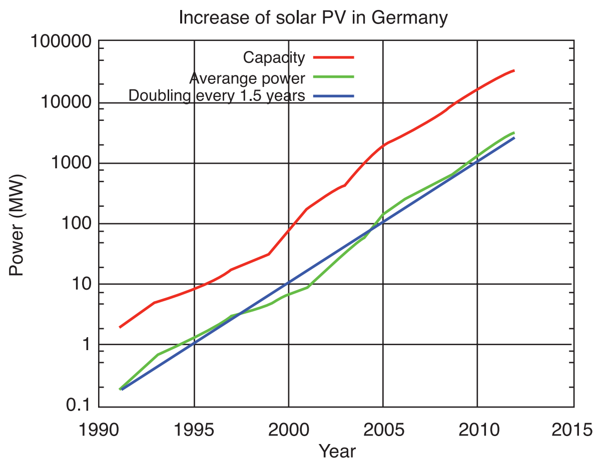
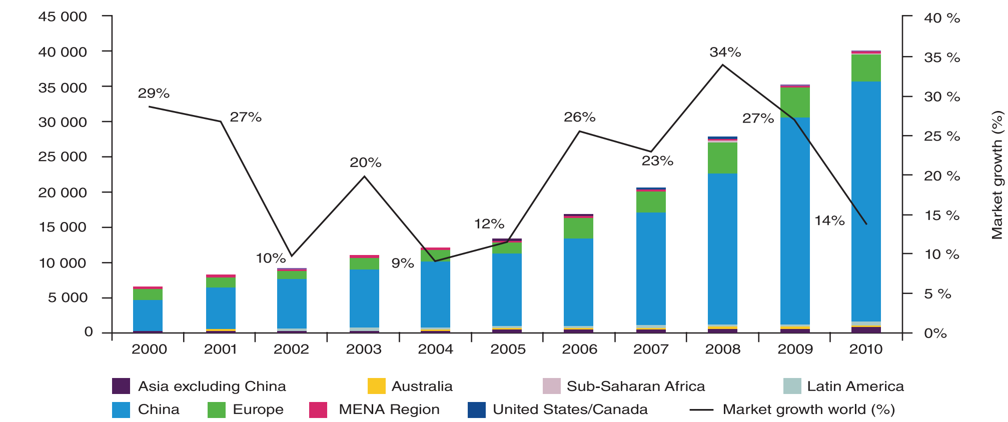


Figure 7.15 The exponential increase of total solar power installations in Germany

The German Renewable Energy Act, effective from the year 2000, has been widely credited for the providing tremendous boost for renewable energies in Germany, resulting in the exponential increase of solar PV installations over the last two decades. The three main principles of the Act are investment protection through guaranteed feed-in-tariffs; zero-effect to Germany's public funds; and constant innovation by tariff regression (periodic lowering of rates to exert cost pressure, hence, driving technology efficiency).

The feed-in-tariff introduced by the German Renewable Energy Act is effective in providing the much-needed financial certainty for renewable energy investments, hence boosting participation. Feed-in-tariff (FIT) is a policy mechanism designed to accelerate investments in renewable energy technologies. It achieves this by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology. In addition, FIT often includes a tariff regression, a mechanism according to which the price (or tariff) ratchets down over time. The goal of FIT is to offer cost-based compensation to renewable energy producers, providing price certainty and long-term contracts that help finance renewable energy investments.

The resulting surge of demands for solar energy systems has created many German solar energy corporations, which include Aleo Solar, Bosch, Belectric, Centrosolar, Centrotherm Photovoltaics and Conergy. In 2011, 20% of electricity in Germany came from renewable sources, and 70% of this was financed by feed-in-tariffs. In addition, the feed-in-tariff generates technology competition and jobs. There are about 340,000 people working in the RE sector in Germany; which is an industry with an estimated turnover of €7.7 billion.



Note: Sub-Saharan Africa: Namibia, South Africa, Zimbabwe. Asia: India, Japan, Korea South, Taiwan. Latin America: Brazil, Chile, Mexico. Europe: Albania, EU 27, Norway, Switzerland, Turkey. MENA Region: Israel, Jordan, Morocco, Tunisia.

Source: Weiss et al., 2012.

Figure 7.16 Annual newly installed capacity of flat-plate and evacuated tube collectors by economic region

Source: EIA 2012

7.3.2 COST-COMPETITIVE SOLAR THERMAL WATER HEATING IN CHINA

Solar thermal heating harnesses the sun's thermal radiation for domestic water and air heating and for industrial processes. China is the world's largest solar thermal heating market with 180.4 GWth, amounting to 69% of global capacity. Over the past 20 years, China's rapid economic development has pushed the demand for solar water heating. The steady growth of solar thermal heating in China is indicated by new thermal collector installations, as shown in **Figure 7.16**.

The key selling point of solar water heaters in China is their cost-competitiveness compared to electric and gas water heaters. For example, in Rizhao city of the Shandong province where about 99% of all households use solar water heating, the initial capital costs for solar water heaters are comparable to that of conventional electric systems. In addition, lifecycle annual savings from solar water heater are about 3-6% of their average household income. While the average annual cost over the lifetime of an electric water heater is USD 95 and USD 82 for a gas water heater, a solar water heater only costs USD 27 annually (IEA 2010).

7.4 CURRENT STATUS OF THE GLOBAL SOLAR ENERGY MARKET

7.4.1 SOLAR PV MARKET AND TRENDS

In 2012, the global solar PV market total operating capacity reached 100 GW (**Figure 7.17**). The world's top solar PV markets are Germany, Italy, China, the US, and Japan, which are also leading in terms of total PV operating capacity (**Figure 7.18**). In terms of solar PV installation per-capita, Germany, Italy, Belgium, Czech Republic, Greece, and Australia are world leaders.

Europe as a whole added 16.9 GW (57%) of new installations in 2012, ending with 70 GW in operation. Other top European markets were France (1.1 GW), UK (0.9 GW), Greece (0.9 GW), Bulgaria (0.8 MW), and Belgium (0.6 MW). All displayed total operating capacity increased by at least 30%, with Bulgaria's capacity rising six-fold.

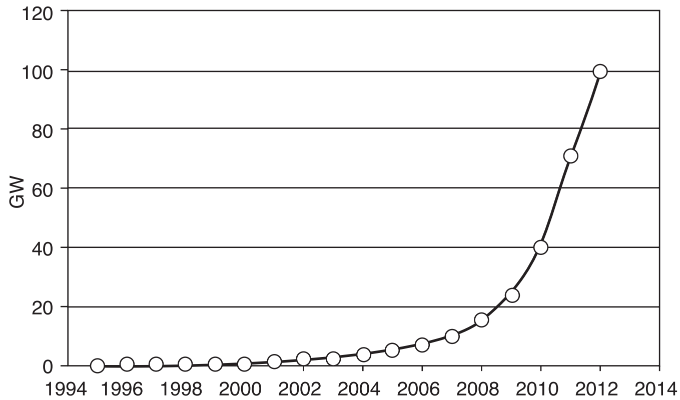
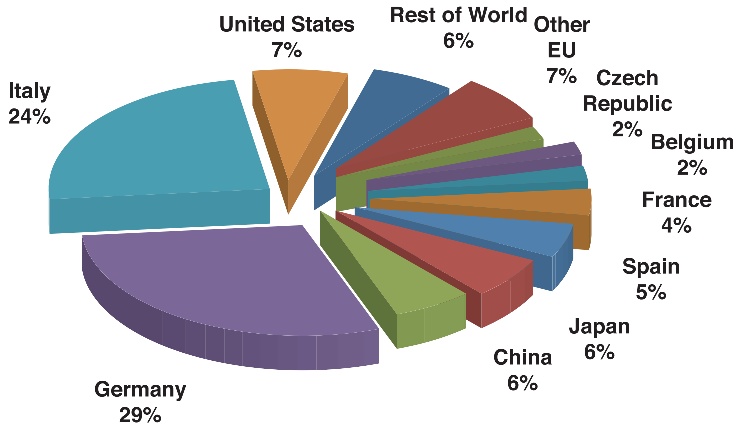


Figure 7.17 Solar PV global capacity 1995-2012

Source: www.ren21.net

Figure 7.18 Solar PV global operating capacity; shares of top 10 countries in 2012 (100 GW)



Source: www.ren21.net

In 2012, 12.5 GW was added elsewhere beyond Europe, up from 8 GW in 2011. The largest non-European markets were China (3.5 GW), US (3.3 GW), Japan (1.7 GW), Australia (1 GW) and India (1 GW). The US capacity increased by nearly 85% in 2012 to 7.2 GW, with California recording more than 1 GW in additions and becoming home to 35% of total US capacity. China had doubled its capacity, ending 2012 with about 7 GW. Meanwhile, Japan's total capacity increased 35% to exceed 6.6 GW, driven by new feed-in-tariffs. Whereas, in 2012, Australia added 2.4 GW, up 70% over 2011. India also experienced significant growth, with a capacity increase of 500% to 1.2 GW. Namibia and South Africa constructed large solar parks in 2012, and Chinese solar companies have been operating in at least 20 African countries spurring demands for Chinese exports. In the middle-east and North African region, the solar PV market is relatively small. The Southeast Asian region has been dominated by Thailand, but markets elsewhere in the region are starting to bloom.

A vast proportion of world's PV capacity is grid-connected, with off-grid capacity accounting for an estimated 1% of the market, down from more than 90% two decades ago. The market for building-integrated PV (BIPV) constitutes less than 1% of solar PV capacity, amounting to an estimated 100 MW added in 2012. Europe is the largest BIPV market with more than 50 companies active in the sector.

The number and capacity of large PV projects continues to grow. In 2013, about 90 plants in operation were larger than 30 MW, and about 400 PV plants had at least 10 MW capacity. The world's 50 biggest plants reached cumulative capacity exceeding 4 GW by the end of 2012, and at least 12 countries across Europe, North America, and Asia had solar PV plants over 30 MW. The world's two largest are the 250 MW thin film plant in Arizona and a 214 MW plant in Gujarat, India. Germany leads for total capacity of facilities larger than 30 MW, with a cumulative 1.55 GW in operation by year's end, followed by the US, France, India, Ukraine, China, and Italy.

The concentrating PV (CPV) market is still relatively small, nevertheless the interest is increasing. In 2012, more than 100 plants totalling as much as 100 MW were operating in at least 20 countries worldwide. The largest capacity with 30 MW is in Colorado, followed by Spain, China and Chinese Taipei/Taiwan, Italy, and Australia. The CPV market is also expanding in North Africa, the Middle East, and South America.

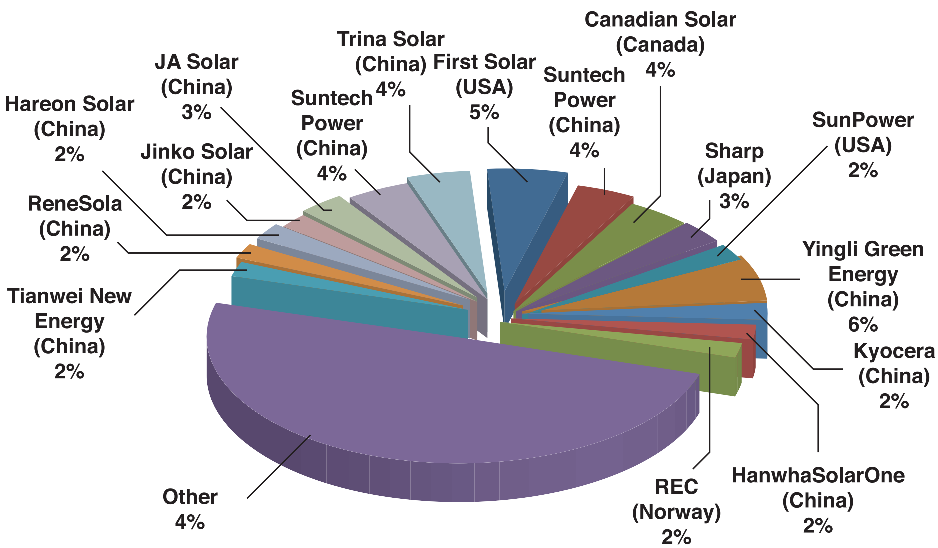


Figure 7.19 Market shares of top 15 solar PV module manufacturers in 2012 (based on 35.5 GW produced in 2012)

Source: www.ren21.net

Figure 7.19 shows the global market shares of top 15 solar PV module manufacturers in 2012, with 11 of these companies hailing from Asia. The industry has a dynamic landscape with constantly changing players. Over the past 15 years, leadership in PV module production, which began with the US, moved to Japan, then to Europe, and currently to Asia. In 2012, Asian countries produced 86% of global market (up from 2% in 2011), with China producing almost two-thirds of the world's total. European market share has continued to fall, from 14% in 2011 to 11% in 2012; and Japan's share has dropped from 6% to 5%. The US share remains at 3%, with thin-film PV accounting for 29% of US production, down from 41% in 2011.

Solar PV manufacturers continue to face formidable challenges to remain profitable. More than 20 US manufacturers have left the industry in recent years due to production overcapacity, and an estimated 10 European and 50 Chinese manufacturers went out of business in 2012. China's top 10 manufacturers borrowed almost USD 20 billion from national banks, while Suntech Power's main operating subsidiary declared bankruptcy in early 2013.

Well-established corporations are not spared from economic turmoil. First Solar and Panasonic closed production lines; GE halted construction on its thin-film factory in Colorado; Bosch Solar announced that it would stop making cells and panels in 2014; Siemens announced closure of its solar business; and Hanwha Group acquired the bankrupt Q-Cells, once a top module manufacturer in 2007. Most companies that remained were investing in improving manufacturing processes and yield, rather than R&D, to minimise their costs. Nevertheless, even as some corporations went out of business, others have ventured into new markets in the developing world. In 2012 to 2013, new PV manufacturing plants were opened in Europe, Turkey, Kazakhstan, Japan, Malaysia, US and Ethiopia's.

7.4.2 SOLAR THERMAL MARKET AND TRENDS

Solar thermal technologies contribute significantly to water heating in many countries, and increasingly to space heating and cooling, as well as for industrial processes. In 2011, nearly 51 GWth was added to the world capacity (**Figure 7.20**), ending with total of 247 GWth. Glazed water systems formed an estimated 49 GWth (>96%) of the market, and the rest was unglazed for swimming pool heating, as well as unglazed and glazed air collector systems.

China and Europe are the world's largest solar thermal market, collectively accounting more than 90% of the market and 81% of total capacity in 2011 (**Figure 7.21**). China, US, Germany, Turkey, and Brazil were the top countries for total operating capacity. The glazed water system market grew 15%, and total global capacity in operation by the end of 2011 was 223 GWth (**Figure 7.22**), providing an estimated 193 TWh (696 PJ) of heat annually.

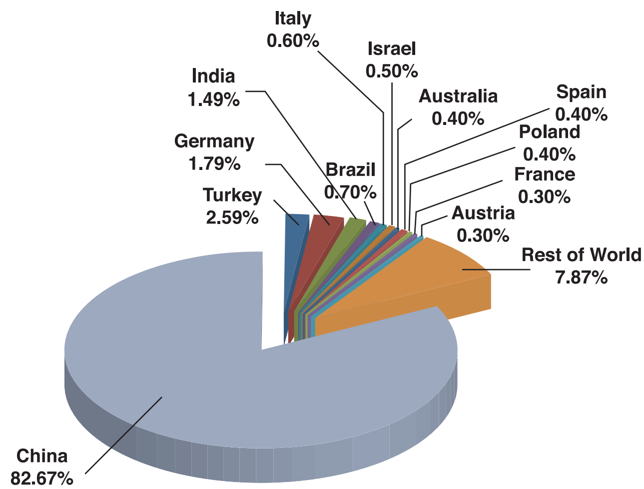


Figure 7.20 Solar water heating global capacity additions; shares of top 12 countries in 2011 (Total Added ~49 GWth)

Source: www.ren21.net

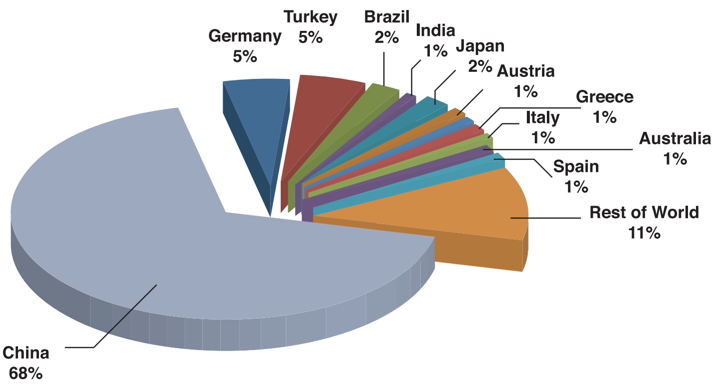


Figure 7.21 Solar water heating global capacity by shares of top 12 countries in 2011 (total capacity ~223 GW th)

Source: www.ren21.net

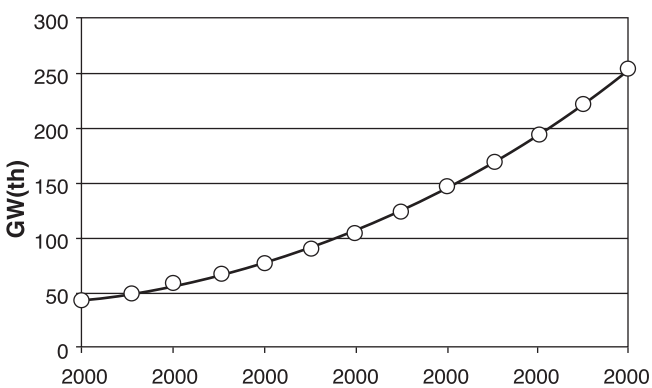


Figure 7.22 Solar water heating global capacity, 2000–2012

Source: www.ren21.net

The 2011 market leaders for newly installed glazed water collector capacity were China, Turkey, Germany, India, and Brazil, which were the same countries leading for total capacity. At end of 2012, global solar thermal capacity in operation reached an estimated 282 GWth. Global capacity of glazed water collectors reached 255 GWth. China was again the main driver of solar thermal demand, adding 44.7 GWth. China's total capacity rose 17.6% (net 27.3 GWth), to 180.4 GWth, which amounts to about 69% of global capacity. European countries accounted for most of the remaining added capacity. Germany was Europe's largest installer in 2012, adding 805 MWth for a total of 11.4 GWth. Japan and India are the largest Asian markets outside of China.

7.5 CURRENT STATUS OF MALAYSIAN SOLAR ENERGY SECTOR

7.5.1 NATIONAL POLICIES FOR PROMOTING SOLAR ENERGY

Malaysia has implemented a number of specific policies, and has set up a national council to support and promote renewable energies. These include the Malaysian Renewable Energy Policy, the National Green Technology Policy, and the Green Technology and Climate Change Council. The Malaysian Renewable Energy Policy is aimed at enhancing the utilisation of indigenous renewable energy resources to contribute towards national electricity supply security and sustainable socio-economic development. The five key strategic thrusts of the policy are as follows:

Thrust 1: To introduce a legal and regulatory framework

Thrust 2: To create a conducive business environment for RE

Thrust 3: To intensify human capital development

Thrust 4: To enhance RE research and development

Thrust 5: To create public awareness and advocacy programs

The policy has the following five specific objectives:

1. To increase RE contribution in the national power generation mix in order to reduce dependency on fossil fuel, contributing towards energy security;

2. To promote the growth of the RE industry and increase its contribution towards the national economy – creating a new industry which will provide new job opportunities;

3. To enhance competitiveness of RE against conventional energy – this will happen when RE electricity achieves grid parity where the cost of RE power is equivalent to the cost of generating electricity using conventional sources;

4. To conserve the environment for future generation by reducing GHG emission from fossil fuel such as gas and coal; and

5. To enhance awareness on the role and importance of RE by getting the buy-ins from the public and decision makers to opt for green energy.

The National Green Technology Policy embodies elements of economic, environment and social policies, as reflected in the five objectives as follows:

1. To minimise growth of energy consumption while enhancing economic development;

2. To facilitate the growth of the Green Technology industry and enhance its contribution to the national economy;

3. To increase national capability and capacity for innovation in Green Technology development and enhance Malaysia's competitiveness in Green Technology in the global arena;

4. To ensure sustainable development and conserve the environment for future generations; and

5. To enhance public education and awareness on Green Technology and encourage its widespread use.

The national goals of the Green Technology Policy are to provide direction and motivation for Malaysians to continuously enjoy good quality living and a healthy environment. The short-term goals, related to RE, of the 10th Malaysia Plan are as follows:

1. To increase public awareness and commitment for the adoption and application of Green Technology through advocacy programs;

2. Widespread availability and recognition of Green Technology in terms of products, appliances, equipment and systems in the local market through standards, rating and labelling programs; Increased foreign and domestic direct investments (FDIs and DDIs) in Green Technology manufacturing and services sectors;

3. Expansion of local research institutes and institutions of higher learning to expand RDI activities on Green Technology towards commercialisation through appropriate mechanisms.

Climate change is an issue that is high on the agenda of the Malaysian government. A Green Technology and Climate Change Council, chaired by the Prime Minister, has been tasked to formulate policies and measures on climate change. The implementation of the Climate Change Policy is aimed at driving efforts to reduce emissions and contribute to the larger agenda of resolving the issue of climate change.

7.5.2 LOCAL MARKET OF SOLAR ENERGY INSTALLATIONS

Malaysia's domestic market for solar energy systems appears to be experiencing encouraging growth over the past recent years, driven by feed-in-tariff (FiT) program which allows electricity that is produced from indigenous RE resources to be sold to power utilities at a fixed premium price for a specific duration.

FiT policies have been very effective in Germany, Spain, and Denmark in stimulating their domestic renewable energy markets, with the long-term aim of achieving grid-parity (the point at which alternative means of generating electricity is equal in cost or cheaper than the conventional grid power). **Figure 7.23** shows the grid parity projected for Europe, US, Japan, and Asian countries

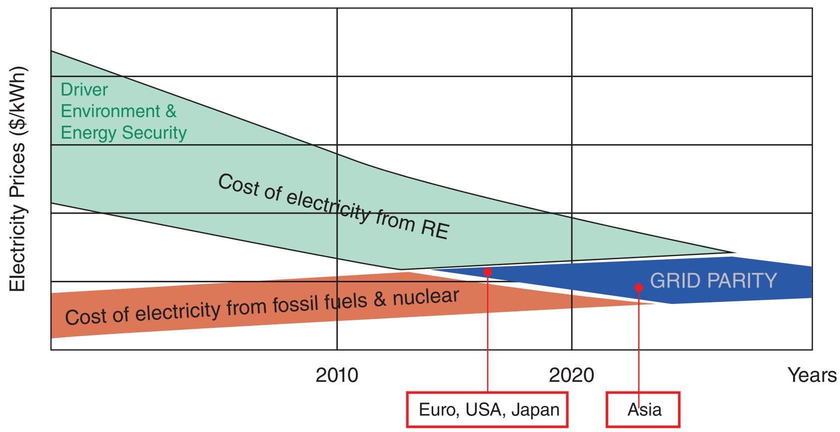


Figure 7.23 Projected point of grid parity for Europe, US and Asian countries

Source: BP REC.

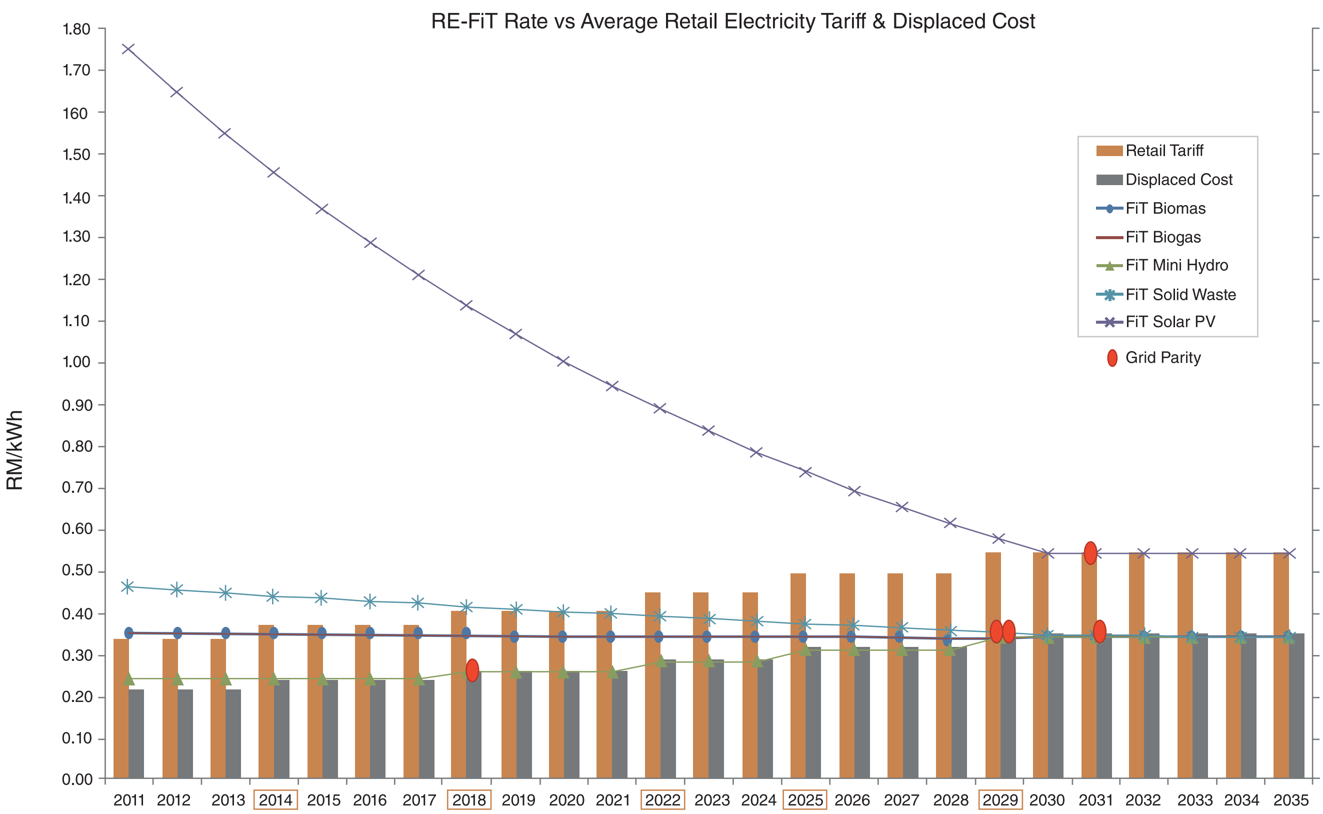


Figure 7.24 FiT digression: Towards grid parity

Source: Ministry of Energy, Green Technology and Water.

Table 7.3 RE Fund cash flow

Year	Average Retail Electricity Tariff (with projected increment)	Annual Electricity Sales (TNB)	Annual 1% Contribution Fee (1% pada 2010 & additional 1% in 2012)	Cumulative RE Fund	Cumulative FiT Cost (Less Displaced Electricity Cost, borne bye TNB)	Implement on Agenvy Annual Fees (3%)	Utility Annual Fees (2%)	Annual Re Fund Balance (Less FiT Cost & Fees)
2009	31.31 sen/kWh	RM 26 Bilion	RM 0	RM 0	RM 0	RM 0	RM 0	RM 0
2010	35.04 sen/kWh	RM 29 Bilion	RM 222 Milion	RM 0	RM 0	RM 0	RM 0	RM 0
2015	38.26 sen/kWh	RM 39 Bilion	RM 783 Milion	RM 2.7 Bilion	RM 1.8 Bilion	RM 17.9 Bilion	RM 11.9 Bilion	RM 764 Milion
2020	42.09 sen/kWh	RM 50 Bilion	RM 1.0 Bilion	RM 7.0 Bilion	RM 6.2 Bilion	RM 29.5 Bilion	RM 19.7 Bilion	RM 376 Milion
2025	46.29 sen/kWh	RM 62 Bilion	RM 1.3 Bilion	RM 12.3 Bilion	RM 11.4 Bilion	RM 27.6 Bilion	RM 18.4 Bilion	RM 371 Milion
2030	50.92 sen/kWh	RM 74 Bilion	Collection Ended	RM 18.9 Bilion	RM 15.1 Bilion	RM 14.9 Bilion	RM 9.9 Bilion	RM 3.0 Bilion
2050	50.92 sen/kWh	RM 92 Bilion	-	-	RM 17.8 Bilion	RM 0	RM 0	RM 140 Milion
CUMULATIVE TOTAL				RM 18.9 Bilion	RM 17.8 Bilion	RM 535 Milion	RM 357 Milion	N/a

Source: Ministry of Energy, Green Technology and Water

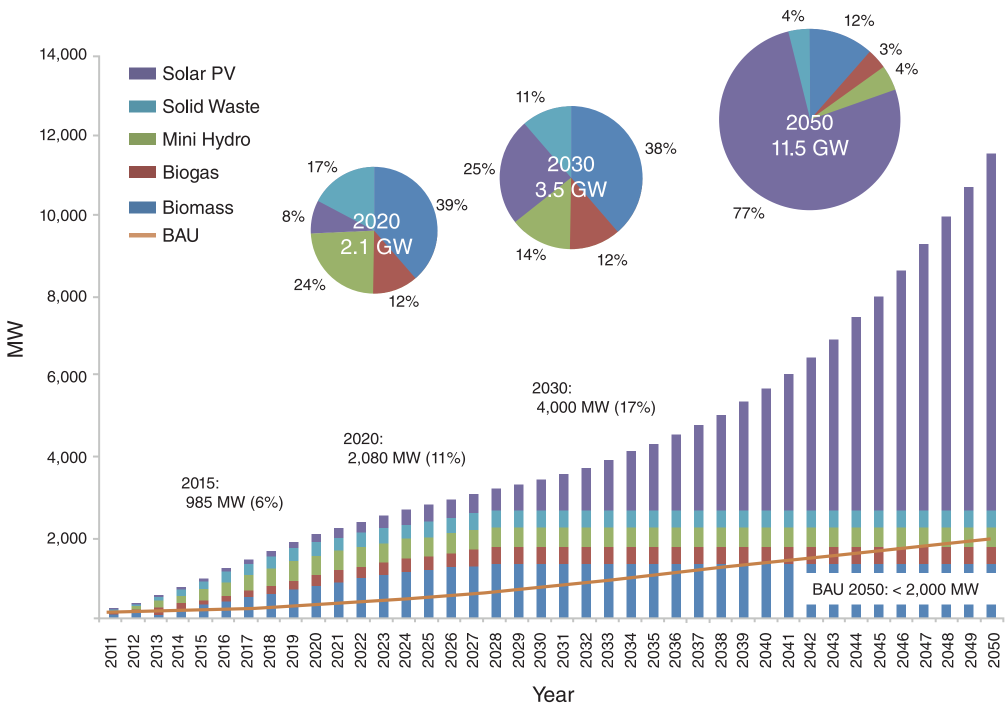


Figure 7.25 Cumulative projected renewable energy installations (2010 – 2050)

Source: Ministry of Energy, Green Technology and Water

Table 7.4 Projected Renewable Energy Growth (2010 – 2050)

Year	Cum Biomass (MW)	Cum Biogas (MW)	Cum Mini-Hydro (MW)	Cum Solar PV (MW)	Cum SW (MW)	Cum Total RE, Grid-Connected (MW)
2011	110	20	60	7	20	217
2012	**150**	**35**	**110**	**15**	**50**	**360**
2015	**330**	**100**	**290**	**55**	**200**	**975**
2020	**800**	**240**	**490**	**175**	**360**	**2,065**
2025	**1,190**	**350**	**490**	**399**	**380**	**2,809**
2030	**1,340**	**410**	**490**	**854**	**390**	**3,484**
2035	**1,340**	**410**	**490**	**1,677**	**400**	**4,317**
2040	**1,340**	**410**	**490**	**3,079**	**410**	**5,729**
2045	**1,340**	**410**	**490**	**5,374**	**420**	**8,034**
2050	**1,340**	**410**	**490**	**8,874**	**430**	**11,544**

Assumptions:

1. RE Technical potential:
   Biomass (EFB, agriculture): **1,340 MW** will be reached by 2028
   Biogas (POME, agriculture, farm): **410 MW** will be reached by 2028
   Mini-hydro (not exceeding 30 MW): **490 MW** will be reached by 2020
   Solar PV (grid-connected): **unlimited**.
   Solid waste (RDF, incineration, sanitary landfill): **378 MW** will be reached by 2024 (at 30,000 tonne,day of Solid Waste projected by KPKT, followed by 3% annual growth post 2024).

Source: Ministry of Energy, Green Technology and Water

With the ultimate aim of achieving grid-parity around the year 2020 to 2030, Malaysia's FiT rates (**Figure 7.24**) are set to encourage private investments in RE and to enlarge the local market for renewable energy systems. The rates are fixed for a period of typically 20 years to give a form of financial certainty and provide businesses with clear investment environment. A special RE fund (**Table 7.3**) was created to pay for the FIT rates (at incremental costs) and guarantee the payment for the whole FIT contract period.) was created to pay for the FIT rates (at incremental costs) and guarantee the payment for the whole FIT contract period.

The Malaysian Ministry of Energy, Green Technology and Water has developed a projection for electricity generated from renewable resources, from the year 2010 to 2050. **Figure 7.25** and **Table 7.4** show the projected cumulative renewable energy system installations for the said period. Going by the projections, Malaysia will have a cumulative RE installations of 11.5 GW by the year 2050, with nearly 80% of the bulk generated by solar PV. However, the projection does not include solar thermal applications.

According to the latest data from Sustainable Energy Development Authority of Malaysia (SEDA), Malaysia has a cumulative solar PV installed capacity of 88 MW, annually generating 45 GWhr of power. When compared as a percentage of total electricity demand, Malaysia's solar PV energy output currently lags behind the neighbouring countries of Thailand, China, Korea and India, which is indicates that Malaysian solar energy market is currently underdeveloped.

7.5.3 LOCAL INDUSTRY PLAYERS

The Malaysian government has dedicated massive investments to jump start the local solar energy industry. Some of the world's most advanced solar PV firms — First Solar (US), SunPower (US), Q-Cells (Germany) — have established their manufacturing facilities in Malaysia, mainly incentivised by the low manufacturing costs. Their finished products are PV cells and modules are then exported out for integration and installation. Besides the foreign-owned solar PV corporations, the local solar energy industry is also participated by a number of local PV and solar thermal manufacturers, and service providers. Examples are:

(a) Local solar service providers providing installation and system integration: Intelligent Power Sdn Bhd, Gading Kecana Sdn Bhd, Zamatel Sdn Bhd

(b) Local solar thermal manufacturers – Solar Tech Sdn Bhd (flat-plate), Microsolar (evacuated tubes), Solarmate Source: *Ministry of Energy, Green Technology and Water*Sdn Bhd

Figure 7.26 Solar Tech Sales & Service Sdn. Bhd

(c) Local solar PV manufacturers: Solartif Sdn Bhd, PV High Tech Sdn Bhd, Malaysian Solar Resources Sdn Bhd, TS Solar Tech Sdn Bhd and HBE Gratings Sdn Bhd;

Figure 7.27 Solartif Sdn Bhd (Kuala Terengganu)

Figure 7.28 Malaysian Solar Resource Sdn Bhd (Gambang, Pahang)

Figure 7.29 PV High Tech Sdn Bhd (Linggi, Negeri Sembilan)

Figure 7.30 HBE Gratings Sdn Bhd (Kajang, Selangor)

Figure 7.31 TS-Tech Sdn Bhd
(Seberang Prai Tengah, Penang)

In Chapter 9, we will discuss the technology value chain of local solar energy industry; where Malaysian companies operate on the chain; and recommendations to transform the Malaysian solar energy sector into a major national industry.

7.5.4 SOLAR ENERGY IMPACT ON MALAYSIA'S NATURAL ENVIRONMENT

Solar energy can potentially make a substantial contribution towards Malaysia's international commitments to reduce emissions of greenhouse gases. Over its lifecycle, a PV system only emits about 21g of CO_2/kWh, depending on the technology. Replacing conventional fossil fuels with solar PV for the purpose of national power may can result in substantial amount of annual CO_2 avoidance. Projected cumulative CO_2 savings from solar electricity generation for the nation between 2011 until 2050 is shown in the **Table 7.5**.

The amount of CO_2 avoidance depends on the conventional power generation method that the solar PV is replacing. Where off-grid PV systems replace diesel

Table 7.5 RE electricity & CO2 avoidance

Year	Annual Biomass GWh	Annual Biogas GWh	Annual Mini-Hydro GWh	Annual Solar PV GWh	Annual SW GWh	Annual RE Electricity (GWh)	Annual CO2 Avoidance (tonne/yr)	Cum Total RE (MW)
2011	675	123	300	7.7	123	**1,228**	**846,975**	217
2015	2,024	613	1,450	60.5	1,223	**5,374**	**3,707,825**	975
2020	4,906	1,472	2,450	192.5	2,208	**11,227**	**7,746,837**	2,065
2025	7,297	2,146	2,450	438.9	2,330	**14,662**	**10,117,015**	2,809
2030	8,217	2,514	2,450	939.4	2,392	**16,512**	**11,393.197**	3,484
2035	8,217	2,514	2,450	1,845	2,453	**17,479**	**12,060,165**	4,317
2040	8,217	2,514	2,450	3,387	2,514	**19,082**	**13,166,594**	5,729
2045	8,217	2,514	2,450	5,911	2,575	**21,668**	**14,950,810**	8,034
2050	8,217	2,514	2,450	9,761	2,637	**25,579**	**17,649,620**	11,544

Assumptions:
1. No loss of RE plant capacity (old plants are replaced or upgraded).
2. RE electricity generation:
    1 MW Biomass (25,000 tonne/year/MV), Biogas generates 6,132 MWh/year (**70%** capacity factor)
    1 MW mini-hydro generates 5,000 MWh/year (**57%** capacity factor)
    1 MW PV generates 1,100 MWh/year (**13%** capacity factor - expected to significantly improve in future)
    1 MW SW (100 tonne/day/MW) generates 6,132 MWh/year (**70%** capacity factor)
3. 1 MWh RE avoids **0.69** tonne CO2

Source: Ministry of Energy, Green Technology and Water generators, they can achieve CO_2 savings of about 1 kg per kilowatt-hour. Replacement of kerosene lamps will lead to even larger savings of up to 350 kg per year from a single 40/Wp module, equalling 25 kg CO_2/kWh. Recycling of PV modules and solar thermal collectors can also result in the energy input for PV manufacturing being further reduced. By 2030, the EPIA-Greenpeace Solar Generation Advanced Scenario estimates that solar PV would have reduced annual global CO2 emissions by over 1.6 billion tons. This reduction is equivalent to the output from 450 coal-fired 750 MW power plants.

7.5.5 SOCIO-ECONOMIC IMPACT OF SOLAR ENERGY ON MALAYSIA

One of the most useful applications of solar energy in Malaysia with various trickled-down socio-economic impacts (comfort, safety, wealth-creation) is the electrification of rural and remote areas. By the end of the transformation initiatives of the GTP 1.0, 99.8% of Peninsular Malaysians have gained access to 24-hour electricity, with 87.7% and 82.7% access for Sabah and Sarawak residents, respectively. The national target is to attain 95% coverage in East Malaysia by 2015 (PEMANDU). **Table 7.6** shows the percentage of rural electrification in Malaysia, from which the need for electricity among rural communities in Sabah and Sarawak is obvious. These needs can be partly satisfied using solar PV technologies via rural electrification programmes shown in **Figure 7.32** and **Figure 7.33**. The table, however, does not show the percentage of households electrified.

Table 7.6 Percentage of Malaysia's rural electrification

Region	2009	2012
Peninsular	99.0 %	99.8 %
Sabah	77.0 %	87.7 %
Sarawak	67.0 %	93.7 %
Total	**82.7%**	**91.7%**

Source: PEMANDU

Figure 7.32 Rural Electrification Programme at Kampung Tuel, Kelantan

Figure 7.33 Rural Electrification Programme in Perak

7.5.6 SOLAR ENERGY APPLICATIONS IN MALAYSIA

7.5.6.1 SOLAR RADIATION IN MALAYSIA

Malaysia lies entirely in the equatorial region. The climate is governed by the regime of the northeast and southwest monsoons which blow alternatively during the course of the year. The northeast monsoon blows from approximately October until March, and the southwest monsoon between May and September. The period of change between the two monsoons is being marked by heavy rainfall. The period of the southwest monsoon is a drier period for Peninsular Malaysia since it is sheltered by the landmass of Sumatra. In general, Sabah and Sarawak receive a greater amount of rainfall than the Peninsular. Hence, heavy rainfall, consistently high temperature, and relative humidity characterise the Malaysian climate.

Much of the precipitation occurs as thunderstorms and the normal pattern is one of heavy falls within a short period. Generally, chances of rain falling in the afternoon or early evening are higher compared to that in the morning. The country experiences more than 170 rainy days. However, an area which has a greater number of rainy days can still receive a lesser cumulative amount of rain as compared to another area with a lesser number of rainy days; but the rains occur in heavy spells. Ambient temperature remains uniformly high over the country throughout the year, between 26.0°C and 32.0°C. Most locations have a relative humidity of 80% – 88%, rising to nearly 90% in the highland areas, and never falling below 60%.

Mapping of solar radiation can give the best preliminary impression of solar radiation intensity of the different areas in Malaysia (**Figure 7.34**). The yearly average daily solar radiation map shows no significant difference in solar radiation intensity between the Peninsular and East Malaysia. On average, Malaysia receives about 4.96 kWh/m^2 of solar radiation a year.

The maximum solar radiation received is 5.56 kWh/m^2, mostly in northern region of Peninsular Malaysia and southern region of East Malaysia. The southern and northeast region of Peninsular Malaysia as well as most parts in Sabah receive the lowest solar radiation. To illustrate, studies done by Kamaruzzaman in 1992 and Ayu Azhari in 2009 revealed nearly similar results, although demonstrated a slight increase in the minimum value, from 3.375 kWh/m^2 in 1992 to 4.21 kWh/m^2, in 2006.

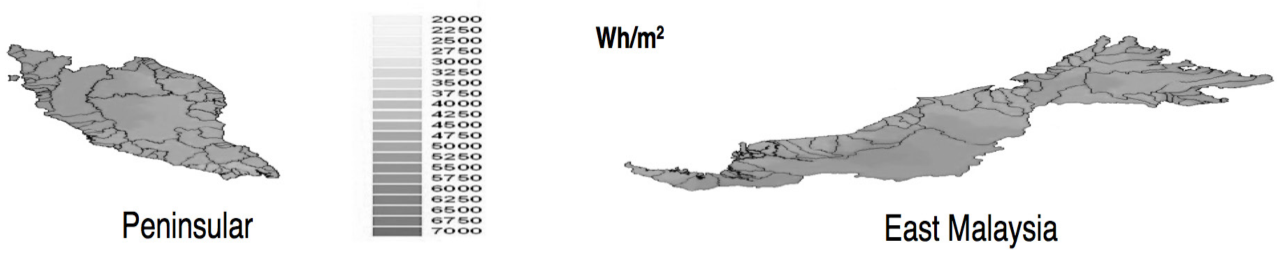


Figure 7.34 Annual average daily solar irradiation of Malaysia

Figure 7.35 to **Figure 7.38** illustrates the monthly average daily solar radiation of Malaysia for the months of January until December. The northern region of Peninsular Malaysia demonsrates the highest potential for solar energy application as this area receives the most solar radiation for almost every month including December. In contrast, the minimum rate of solar radiation received by this area is estimated to be higher than that of 3.0 kWh/m^2. Apart from that, a few other areas in East Malaysia also show the potential in solar energy application as these areas receive from average to very high solar radiation especially between May to November. The lowest solar radiation estimated for East Malaysia is recorded in December until January.

In studies by Chuah and Lee (1984) as well as Kamaruzzaman and Mohd Yusof (1992), the lowest solar radiation was recorded in northeast of Peninsular Malaysia. A more is study in 2006, however, revealed that the lowest solar radiation was received in southern region of Peninsular Malaysia in December. The minimum solar radiation was estimated to be at 0.61 kWh/m^2. This was supported by the recent flood tragedy in most areas of the southern region in December 2006.

Looking at the bigger picture, there seems to be an increase in solar radiation from 1982 recorded by Chuah and Lee, compared to another study by Kamaruzzaman and Mohd Yusof in 1992 and a recent study in 2006. The average minimum solar radiation has increased from 3.07 kWh/m^2 in 1982 to 3.373 kWh/m^2 in 1992; and in 2006 the average minimum solar radiation for Malaysia was estimated to be 4.21 kWh/m^2. This indicates that solar radiation in most places in Malaysia is increasing. This is also indicated by the slight increase in average solar radiation from 4.8 kWh/m^2 in 1982 to 4.965 kWh/m^2 in 2006. The average maximum solar radiation also showed a slight increase from 5.47 kWh/m^2 in 1982 to 5.572 kWh/m^2 in 1992.

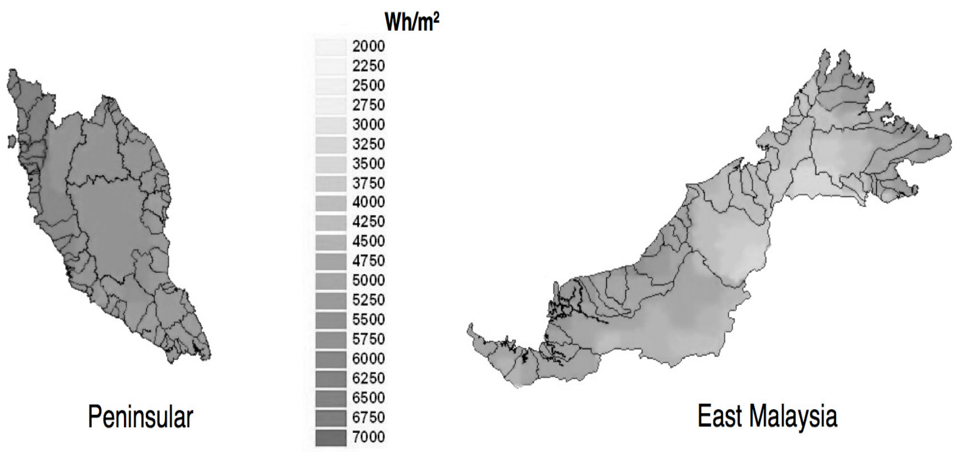


Figure 7.35 Monthly average daily solar irradiation of Malaysia for the month of January

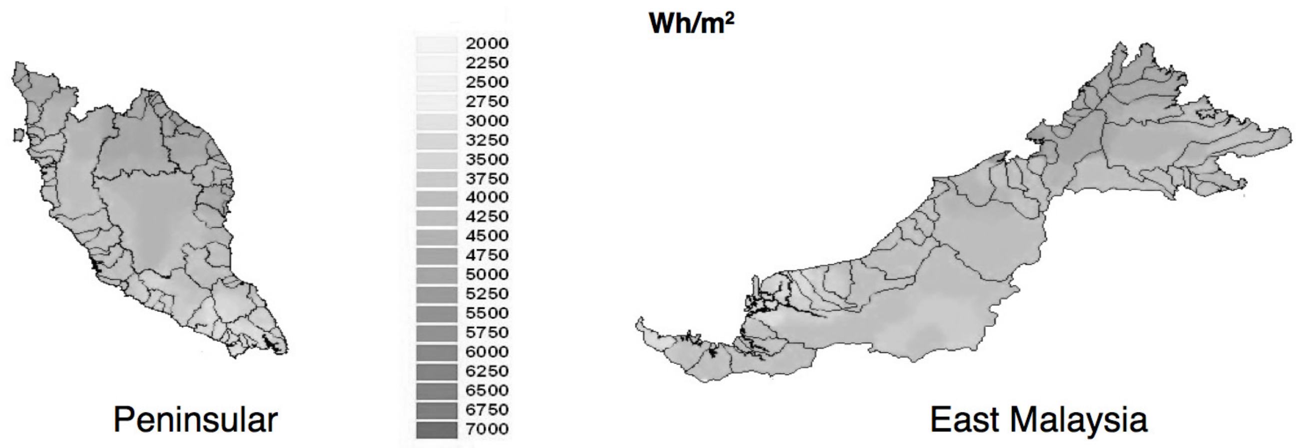


Figure 7.36 Monthly average daily solar irradiation of Malaysia for the month of April

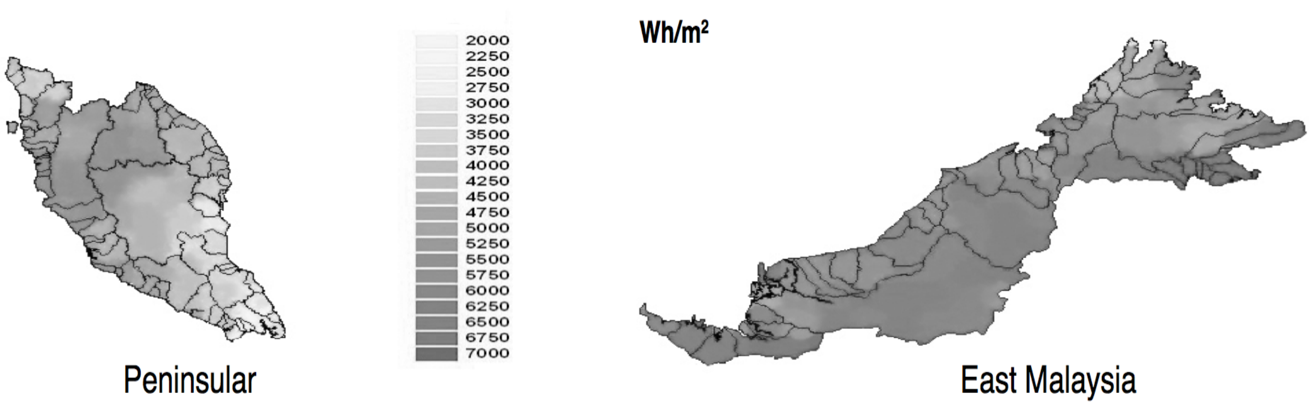


Figure 7.38 Monthly average daily solar irradiations of Malaysia for the month of December

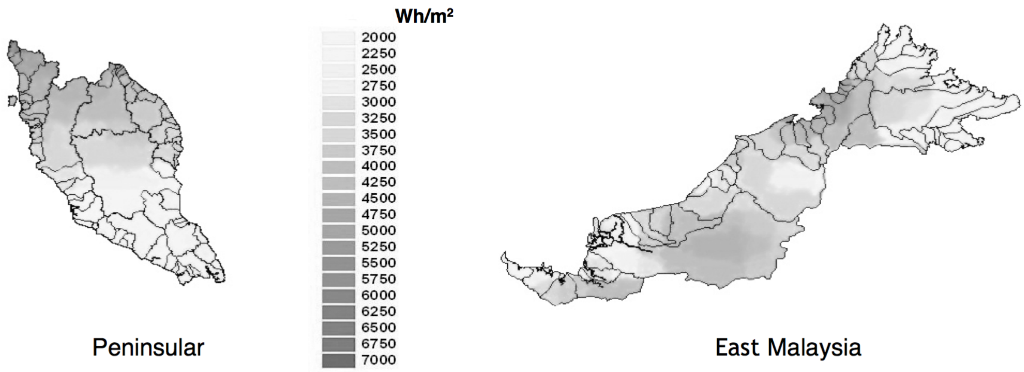


Figure 7.38 Monthly average daily solar irradiations of Malaysia for the month of December

Solar radiation in the tropics is unique because it is characterised by the diffused nature of the solar radiation, due to the presence of cloudy conditions in the equatorial region. Therefore, the use of concentrating technologies is not practical in this area because such technologies utilise the direct component of solar radiation.

7.5.6.2 STANDARDS DEVELOPMENT

Standards generally applied for PV panels are the IEC 61215 (crystalline silicon performance), 61646 (thin-film performance) and 61730 (all modules, safety), ISO 9488, UL 1703, CE mark, and Electrical Safety Tester (EST) Series (EST-460, EST-22V, EST-22H, EST-110). No local testing and standardisation facilities are available in Malaysia. Certification can be conducted at recognised standardisation centres in Germany, United States and Taiwan.

Module performance is generally rated under Standard Test Conditions (STC): irradiance of 1,000 W/m², solar spectrum of AM 1.5 and module temperature at 25°C. Electrical characteristics include nominal power (PMAX, measured in W), open circuit voltage (V_{OC}), short circuit current (I_{SC}, measured in amperes), maximum power voltage (VMPP), maximum power current (IMPP), and module efficiency (%). Solar modules are also rated in 'kWp', where 'kW' is kilowatt and 'p' is 'peak'. The 'p', however does not indicate peak performance, but rather the maximum output according under Standard Testing Conditions. Solar panels must withstand heat, cold, rain and hail for many years. Many crystalline silicon module manufacturers offer warranties that guarantee electrical production for 10 years at 90% of rated power output and 25 years at 80%.

The standards for solar thermal collectors are of ISO 9806 which comprise of: Test methods for solar collectors; EN 12975: Thermal solar systems and components - Solar collectors; EN 12976: Thermal solar systems and components — Factory made systems; and EN 12977: Thermal solar systems and components — Custom made systems (ISO 9806-2:1995. Test methods for solar collectors Part 2: Qualification test procedures. International Organisation for Standardisation, Geneva, Switzerland).

7.5.6.3 STANDALONE PV SYSTEM APPLICATIONS IN MALAYSIA

In Malaysia, stand alone PV systems find useful applications in rural electrification. **Table 7.7** lists the locations and capacity of standalone PV systems in the rural areas of Malaysian States. The total installed capacity for rural electrification is 1589.65 kWp, with most of the standalone PV systems being applied for telecommunication equipment.

Table 7.7 Locations of standalone solar PV systems

Locations	Capacity (kWp)
Sabah	616.330
Sarawak	594.125
Kelantan	75.440
Perak	75.965
Pahang	100.129
Johor	127.571
TOTAL	1589.56

One of the earliest rural electrification projects, as shown in **Figure 7.39**, was installed in Langkawi Island in the early 80's. The application of PV systems for rural electrification was first initiated by the then National Electricity Board (now TNB) in early 1980's. The first of these was the installation of standalone PV systems for 37 houses in Langkawi, followed by other projects in Tembeling (70 houses) and Pulau Sibu (50 houses). Later on in the 1990's, two rural electrification pilot projects, of 10 kWp and 100 kWp respectively were implemented in Sabah with the support from the New Energy Development Organisation (NEDO) of Japan.

Figure 7.39 Among the earliest standalone rural telecommunication and electrification projects in Malaysia

A solar PV installation in Malaysia would typically produce an energy output of about 900 – 1400 kWh/kWp per year, depending on location. Areas located at the northern and middle part of the Peninsular and the coastal part of Sabah and Sarawak would yield higher performance. An installation in Kuala Lumpur would yield around 1100 kWh/kWp per year. Other common applications are powered by stand alone PV systems are street and garden lighting, and parking ticket dispensing machines in Petaling Jaya and other cities. **Figure 7.40** shows an experimental 1.2 kWp standalone water pumping system donated by NEDO to UKM in 1980.

Figure 7.40 1.2 kWp water pumping system

7.5.6.4 HYBRID PV SYSTEM APPLICATIONS IN MALAYSIA

Hybrid PV systems are found in a variety of applications in Malaysia, including education and research, tourism, and rural electrification. A hybrid PV diesel hybrid system installed at the Nature Education and Research Centre (NERC) in Pahang has a total of 112 solar modules with a total array power of 10 kW, with the diesel generator having a capacity of 6 kW (**Figure 7.30**).

The ground access to NERC is via a winding dirt road about 2 hours' drive from the nearest town of Kahang located 60 km away. The Centre was initially co-funded by the Danish Cooperation for Environment and Development (DANCED) and the Malaysian Nature Society (MNS), and is now managed by the Perbadanan Taman Negara Johor (PTNJ). The Chief Minister of Johor officially opened the Centre on 24th March 2001.

A diesel-powered generator powers the NERC administration complex at night. The estimated PV array conversion efficiency is 13.8%, with performance ratio of 77%. The system cost is RM62.57 per Wp installed and its estimated PV energy generation cost is RM3.15 per kWh. The maintenance of the system is relatively low except for the diesel generator, which has been experiencing breakdowns and requires a battery replacement every five years. The system is estimated to provide a net abatement of 225 tons of CO_2 emissions during its lifetime.

Figure 7.30 PV-Diesel hybrid system at the Nature and Research Centre, Endau-Rompin National Park

The hybrid PV systems installed at Middle and Top Stations of Langkawi Cable Car at Gunung Machinchang shown in **Figure 7.31** is the first solar energy installation for a tourist complex in the country. The hybrid PV systems serve the electrical demands of the cable car stations, which include water pumps, controllers, air-conditioners and lightings. The project is owned by LADA and is operated by Panorama Langkawi Sdn Bhd The electrical capacity for each station is as follows:

	Middle Station	Top Station
PV Array	8 kW	8 kW
Diesel generator	60 kVA	60 kVA
Battery	269 kWh	250 kWh
Inverter	30 kVA	30 kVA

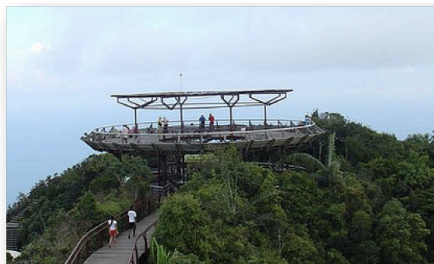


Figure 7.31 Hybrid PV system installed at the Langkawi Cable Car at Gunung Machinchang

Wind turbines can also be incorporated into a solar stand-alone PV system. The wind turbine-solar PV hybrid system shown in **Figure 7.43** was installed in April 2010 at Kuching Waterfront as part of a pilot and educational project by SIRIM, iWind Energy (M) Sdn Bhd and Sri Waja Resources Sdn Bhd, under the Ministry of Science, Technology and Innovation (MOSTI).

Figure 7.32 PV-wind hybrid system at Kuching Waterfront

A diesel-PV hybrid system in the orang *Asli* residence of Kampung Denai, Rompin, Pahang is used to light 15 houses and a school. Kampung Denai is located 35 kilometres from the nearest main road connecting Rompin and Mersing. The total population is 158, which is scattered in 22 houses. The system consists of 10 kW PV panel, 10 kW inverter, 150 kWh battery and 17.6 kW generator set. The maximum demand was measured at 4195.35 kW.

7.5.6.5 GRID-CONNECTED PV SYSTEMS IN MALAYSIA

Grid-connected PV systems are gaining a foothold in the Malaysian energy landscape. **Table 7.8** shows the annual power generation by commissioned RE installations under the FiT system, where it can be seen that solar-generated power records the second biggest yearly increase. **Table 7.9** shows the total installed capacities of commissioned RE installations under the FiT mechanism, from which it can be seen that solar PV records the biggest total capacity. Both tables indicate that solar PV is a leading and preferred renewable energy resource in Malaysia. As electricity generation from renewable resources displaces fossil fuels, the overall greenhouse gas emissions from the fossil fuel power stations can be substantially reduced (**Table 7.10**).

Table 7.8 Annual power generation (MWh) of commissioned RE installations

Year	Biogas	Biogas	Biomass	Biomass (solid waste)	Small hydro	Solar PV
2013	2445.85	5986.91	158054.73	4212.76	49456.47	18287.38
2012	97.11	7465.40	97019.06	3234.52	25629.78	4707.17

Source: SEDA Malaysia

Table 7.9 Installed capacity (MW) of commissioned RE installations

Year	Biogas	Biogas	Biomass	Biomass (solid waste)	Small hydro	Solar PV	Total
2012	2.00	3.16	43.40	7.90	15.70	31.53	104.69
2013	3.38	0.00	0.00	0.00	0.00	12.50	15.88
Cumulative	5.38	3.16	43.40	7.90	15.70	44.03	120.57

Source: SEDA Malaysia

Table 7.10 Annual power generation (MWh) of commissioned RE installations and CO_2 avoidance

Year	Biogas	Biogas	Biomass	Biomass (solid waste)	Small hydro	Solar PV	CO_2 avoidance (ton)
2013	1755.34	9282.09	176000.92	5137.62	51809.51	15866.93	259853.41
2012	67.70	5151.13	66943.15	2231.82	17684.55	3247.95	95326.3

Source: SEDA Malaysia.

A study by PTM/DANIDA entitled "Study on Grid Connected Electricity Baselines in Malaysia" measured the overall average emission factor for Malaysia and Sabah to be 0.69 $kgCO^2eq/kWh$. This was calculated using a methodology adopted by United Nations Framework Convention for Climate Change (UNFCCC) and the International Panel on Climate Change (IPCC), and is based on the combined margin for power generation.

More RE power plants are being planned and constructed, which will increase the overall proportions of electricity generated by RE. **Table 7.11** lists the total RE capacities under the FIT mechanism but have not yet achieved the FIT Commencement Date. It seems that solar PV will be a significant renewable energy resource in Malaysia for years to come.

Table 7.11 Installed capacity (MW) of plants in progress

Year	Biogas	Biogas	Biomass	Biomass (solid waste)	Small hydro	Solar PV	Total
2012	0.00	5.20	12.50	0.00	0.00	25.78	43.48
2013	2.90	4.00	47.50	0.00	27.30	92.23	175.93
2014	2.40	1.20	24.00	11.09	49.05	31.40	119.15
2015	0.00	0.00	0.00	0.00	27.00	0.00	27.00
Cumulative	5.30	10.40	85.00	11.09	105.35	149.40	366.55

There are two types of grid-connected PV system utilising the Feed-in-Tariff in Malaysia, namely the building integrated PV (BIPV), and the solar farm. An example of a BIPV system is presented in **Figure 7.33**. The biggest solar farm under the FiT scheme in Malaysia is located at Pajam, as shown in **Figure 7.34**. The 8 MW solar farm is located on a closed landfill ground, exporting electricity to the TNB grid at a special tariff of RM 0.90/kWh. Daily generating capacity of the solar farm (kWh) reaches 85 % x 8 MW x 5 hours on average.

Figure 7.33 Building-Integrated Photovoltaic (BIPV) in Shah Alam

Figure 7.34 (Eight MW) 8MW grid-connected solar farm in Pajam

7.5.6.6 SOLAR-DRYING APPLICATIONS IN MALAYSIA

In Malaysia, all agricultural crops are traditionally dried in the sun. The present post-harvest drying systems for selected tropical agricultural produce are shown in **Table 7.12**. Harnessing solar energy for drying process can be achieved without much difficulty because there are many innovative ways of using solar-assisted drying systems for agricultural produce, depending on the required drying temperature and duration.

Table 7.12 The present post-harvest drying systems for tropical agricultural produce

Produce	Present drying system	Energy source	Drying time
Paddy	(a) Open drying	Sun	5 – 6 hours
	(b) Fixed bed dryer	Diesel	4 – 5 hours
	(c) Moisture extraction	Diesel/Electric	2 – 3 hours
Cocoa	(a) Sundry	Sun	6 days
	(b) Kerosene drying	Kerosene	35 – 40 hours
	(c) Burner blower	Kerosene/Diesel	36 hours
	(d) Rotary drying	Diesel	45 – 48 hours
Coffee	Sundry	Sun	14 days
Pepper	Sundry	Sun	7 days (black pepper)
			3 days (white pepper)
Tobacco	Conventional curing	Rubber wood	100 hours
		LNG	100 hours

Tea	Drying chamber	Diesel	25 min at 95°C
Banana	Sundry	Sun and wood	1 day
Anchovies	(a) Sundry (b) Fixed bed dryer	Sun Diesel	7 days 5 – 7 hours
Seaweeds	Sundry	Sun	10 days
Rubber	Sundry	Sun and wood	1 day

Although solar-drying process is technically simple, there are currently very few take-ups for solar-drying systems in Malaysia. Local universities and research institutes have experimented solar-drying of various products. The Malaysian Agricultural Research and Development Institute (MARDI) has carried out solar-drying activities on many agricultural commodities including paddy, tapioca, groundnuts, noodles, vermicelli, coffee beans, tobacco, *keropok*, mussels, anchovies, banana and fish. **Error! Reference source not found.** shows a solar-drying system for oil palm fronds presently used by FELDA in an oil palm mill in Kuantan.

Most commercial applications of solar-drying systems typically have an attractive payback period of less than 3 years, replacing a conventional diesel-powered dryer. Nevertheless, the utilisation of solar-drying technology in Malaysia is still currently low. However, this is expected to change with the expected price increase of diesel in the future.

Error! Reference source not found. Solar-assisted drying system for oil palm fronds.

7.5.6.7 SOLAR HOT WATER HEATING APPLICATIONS IN MALAYSIA

One of the most attractive applications of solar energy is for water heating in the public and commercial sectors. A case study of such facility (**Figure 7.**)is located at the Hospital Universiti Kebangsaan Malaysia (HUKM), which is funded by the Ministry of Science, Technology and Innovation (MOSTI) via Technofund; its research fund.

In a previously installed conventional heating system, cold water enters the calorifiers which are heated by LPG boilers. Boiling time is relatively long, hence, a large amount of LPG fuel is used and significant amount of greenhouse gases are released. Each boiler has a heating capacity of 2.1 million kcal/hr, with a total of 8 calorifiers used. Each calorifier has a capacity of 13,500 litre/hr, with each unit running 24 hours a day. Installing solar collectors would generate 3,180 MJ/day, assuming 70% collection efficiency. The resulting LPG savings are estimated to be 29,000 kg/year, with approximated CO_2 reduction of 64,000 kg/year. With a prospect of 100 hospitals and hotels throughout the nation, the installation of solar collectors for their hot water requirements would result in an even bigger collective LPG savings at the national scale.

Figure 7.47 Solar hot water heating system for hospitals

7.6.7 R&D ON SOLAR ENERGY TECHNOLOGIES IN MALAYSIA

R&D in solar thermal technology is conducted around the world with the chief aim to increase cell efficiencies, and to discover innovative methods of cost-cutting. Malaysian universities and research institutes have well-established R&D programmes in solar PV technologies including chargers and inverters, and also in solar thermal systems for drying, cooling, water heating, detoxification and desalination. The following is a snapshot of solar energy R&D by local universities and research agencies:

(1) Universiti Sains Malaysia (USM): The School of Physics and the Centre for Education, Training, and Research in Renewable Energy and Energy Efficiency (CETREE) together with Pusat Tenaga Malaysia (PTM) carry out advocacy programs through the SURIA1000 project to raise public awareness on the positive attributes of renewable energies and energy efficiency. The Centre's other activities consist of fundamental research in solar cells, especially in thin-film technologies.

Figure 7.35 Renewable energy powered bus in CETREE, USM

(2) Universiti Teknologi MARA Malaysia (UiTM): The UiTM National PV Monitoring Centre (PVMC) monitors all grid-connected BIPV systems implemented under the MBIPV project. It is responsible for collecting relevant data and statistics of all PV systems in Malaysia. In addition, the Institute of Science, a research arm of UiTM, was set up with the aim of enhancing and strengthening the Science and Technology agenda of the university. UiTM's research on solar thermal systems is conducted in UiTM's Centre of Innovation in Sustainable Energy.

Figure 7.36 UiTM Photovoltaic Monitoring Centre (PVMC), UITM

(3) UM: UMPEDAC is responsible in the R&D of local stand-alone PV systems for urban and remote applications. The project is expected to produce the first Malaysian-made PV system. Research and development on organic solar cell is conducted in the UM's Chemistry Department.

(4) UTM has established the Quality Control Centre (QCC) which conducts quality-assurance and failure-investigation of solar energy systems. The university also has an established solar automotive group, which has participated in many solar car races throughout the world.

Figure 7.37 UTM Solar Car

(5) UKM: UKM's Solar Energy Research Institute (SERI) is responsible for fundamental and applied research, and development of solar energy technologies. Among the research focus of SERI include advanced textured silicon solar cell; back contact interdigitated crystalline silicon solar cells; and innovative manufacturing of thin film solar cells such CdTe and CIGS solar cells. SERI's research facilities include an advanced silicon solar cell fabrication laboratory, thin-film laboratory, solar simulator, grid-connected and stand-alone PV system. Solar thermal research conducted in the Green Energy Technology Innovation Park (**Figure 7.38**) is focused on photovoltaic thermal collectors, low-energy house, and solar thermal experimental unit (drying, dehumidification, heat pump, cooling systems). SERI has 15 full-time research fellows and 60 doctoral candidates. SERI also currently offers MSc and PhD degrees in RE.

Figure 7.38 Green Technology Innovation Park, UKM

(6) SIRIM Bhd: SIRIM conducts applied research in solar thermal and photovoltaics, including PV-hybrid system, grid-connected photovoltaics, BIPV and solar-drying systems for agricultural and marine products. SIRIM have also conducted studies of hybrid system applications in remote locations in Sabah.

Figure 7.52 Solar dryer for fish in Sabah (SIRIM)

(7) Universiti Malaysia Sabah (UMS): UMS is actively involved in solar-drying of seaweeds in Semporna, targeted for local and export markets.

Figure 7.39 Solar cooker (UMS)

(8) Forest Research Institute of Malaysia (FRIM): FRIM has developed solar dehumidification system for timber and flowers.

(9) Malaysia Agricultural Research and Development Institute (MARDI): MARDI has experimented with solar-drying of many agricultural produce including paddy, tapioca, groundnuts, noodles, vermicelli, coffee beans, tobacco, keropok, mussels, anchovies, banana, and fish.

Figure 7.54 Solar dryer for oil palm fronds (MARDI)

Figure 7.55 Grid-connected dense array concentrator PV system

(3) UNIMAS: CoERE was established in 2009 by UNIMAS to carry out R&D in all renewable energy technologies. CoERE is dedicated to accelerate the deployment and grid-integration of renewable energy and low-carbon generation technology through the utilisation of wind, tidal, biomass, hydro, and solar energies.

(4) UTAR: UTAR conducts research and development in solar photovoltaic and thermal systems. Examples of such projects are Grid-Connected Dense Array Concentrator Photovoltaic System and Intelligent Active Management System for Micro-Grid with Renewable Energy. Another solar thermal project is the non-imaging focusing heliostat system.

7.6 DESIRED FUTURE OF SOLAR ENERGY IN MALAYSIA

To determine the desired outcomes for the future of solar energy in Malaysia requires a lot of consideration, because such indicators not only must be SMART (Specific, Measureable, Attainable, Relevant, Time-bound), but also inclusive enough to cover the social, economic and environmental dimensions, ensuring holistic approach of sustainable national development. For example, while the economic indicators may be concerned about cost and utilisation levels of solar energy systems, the social indicators may be measured against public awareness of an energy-efficient lifestyle, while environmental indicators concern on regulating (and promoting) technology development and deployment. These dimensions are shown in **Table 7.13** and **Figure 7.56**, along with a framework for the development of such indicators.

Table 7.13 Dimensions of sustainable development and indicators

Dimensions of sustainable development	Energy priority areas	Energy related topics	Relevant energy indictors
Social	Improving quality of life in term of social well-being	Accessibility	EISD1: Rural electrification coverange by reion (%)
		Affordability	EISD2: Share of electricity spending in total household expenditure for different income groups (%)
		Disparities	EISD3: Share of electricity subsidy reveiced among different income groups (%)
Economic	Ensuring sufficiency and cost-effectiveness of energy supply; Improving energy efficiency; Increasing utilisation of renewable energy	Overall use	EISD4: Energy use per capita
		Overall Productivity	EISD5: Energy use per GDP
		Production	EISD6: Rate of self-sufficiency
		End Use	EISD7: Shares of sectoral energy demand in total energy consumption
			EISD8: Sectoral Energy Intensities
		Diversification (Fuel Mix)	EISD9: Fuel shares in energy and electricity
			EISD10: Renewable energy share in energy and electricity
		Prices	EISD11: End-use energy prices by fuel
		Fuel reserves	EISD12: Reserves-to-production-ratio
Environmental	Minimising the energy impact on the environment	Climate Change	EISD13: GHG emission from energy consumpstion per unit of GDP
		Air Quality	EISD14: Shares of emission loads from energy sector in air pollutant emissions (%)

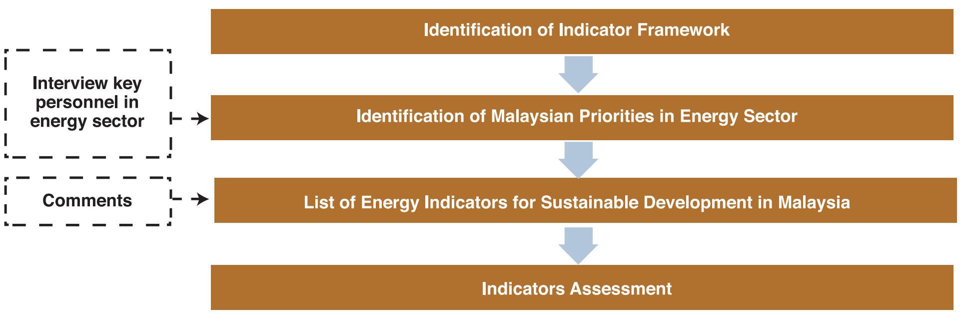


Figure 7.56 Energy indicator development processes

In 2011, acting under a commission by the Malaysian Government, the World Bank released a report recommending strategies for Malaysia to move up the value chain of global solar energy industry. Among the general recommendations made are:

"*Instead of relying on foreign investors to import mass production manufacturing technology and to integrate the country into the global economy, a country moving up the value chain will need to focus on enhancing the technological and organisational capacity of local firms so that they themselves have the capacity to design, produce, and market more knowledge intensive, higher value added products. Policy will have to focus on developing local capabilities and entrepreneurship and helping these local firms insert themselves into global value chains, which may entail attracting venture capital, entrepreneurial mentors, quality control experts, and technology acquisition capacity rather than foreign investors looking to establish low-cost assembly operations.*

Moving up the value chain entails consulting extensively with stakeholders and establishing business-science-university-government councils to ensure that education and research programs are geared towards the needs of these emerging sectors. Moving up the value chain also entails giving research institutes and universities the autonomy they need to react quickly and flexibly to changing needs and demand."

(Source: STI Report, World Bank 2011)

The general recommendations by the World Bank report are in line with Malaysian government's aspirations to move up the technology value chain. These have been partly implemented with the Government's various roles and investments in developing local R&D talents, as well as the enforcements of investment-friendly energy policies.

Based on these premises as well as feedback gathered from various stakeholders, we have expanded the desired outcomes and key indicators for the Malaysian solar energy industry to cover the three dimensions of sustainable developments, which are economic, social, and governance aspects. **Table 7.14** lists the desired outcomes and key indicators for the Malaysian solar energy sector. The specific action plans and roadmap to achieve the desired outcomes are discussed in Chapters 9 and 10.

Table 7.14 Desired outcomes and indicators for the Malaysian solar energy sector

Desired outcomes	Indicators
Economic	
1. Sustained growth of Malaysian market share for solar PV and solar thermal production, eventually being in the league of global top 10 producers	1. Market indicators of global solar energy industries 2. Industry indicators: investments, revenues, jobs, market trends, intellectual properties, operational capacity, installation capacity, energy costs technology efficiencies, R&D expenditures 3. Renewable energy share in the electricity generation mix
2. Formation of an ecosystem of local SMEs and MNCs providing value-added support and services throughout the entire technology value chain; from the upstream R&D, feedstock supplies and PV manufacturing to downstream system services	
3. A growing proportion of national energy generation from solar power, eventually achieving grid parity by 2030 with at least 20% of domestic energy needs generated from renewables	
4. A growing demand for solar PV and thermal systems that would result in substantial expansion of local market for solar power installations	
Social	
1. A growing pool of local R&D talents and high-skilled workers in solar energy industry	Number of skilled workers, facilities, patents, IP, academic publications, R&D expenditures. Public opinion polls
2. Increased public awareness and practices on clean energies and energy-efficient lifestyle	

Governance	
1. Enforcement of effective market-intervention measures to stimulate domestic demands and investments in solar energy	1. Government energy roadmaps 2. Market data on investments in solar energy 3. Significantly increased proportion of energy generation from renewable sources
2. Introduction of attractive financing schemes to support domestic installation of solar energy systems	
3. Roll-out of incentive programs to promote private R&D investments in solar energy technologies	
4. Business-friendly energy policies that increase energy generation from renewable sources, particularly solar	

7.7 CONCLUSION

Solar energy is one the world's fastest growing renewable energy resources in terms of technology development and deployment. Its phenomenal global growth is collectively driven by supportive regulatory policies, worldwide concerns of energy security and environmental preservation, and ever-decreasing technology costs. Malaysia is poised to reap substantial economic and social benefits from solar energy considering that it already has established much of the necessary groundwork, which include regulatory framework, quality investments in R&D talents and facilities, and a history of small-scale commercial applications.

Malaysia is also the manufacturing base of some of the world's most advanced solar energy firms, which are mostly capitalising on Malaysia's local low-cost labour. However, in order to fully realise Malaysia's potential, proactive measures must be implemented for Malaysia to move up the technology value chain. In the next chapter, we discuss the global value chain of solar energy industry, and we propose strategies for Malaysia to lock in and domestically generate higher value-added, while simultaneously stimulating the domestic solar PV market.

CHAPTER 8

SOLAR AS AN EFFICIENT RENEWABLE ENERGY - BASELINE STUDY: GLOBAL DRIVERS,TECHNOLOGY OVERVIEW, CASE STUDIES, MARKET TREND, MALAYSIA'S CURRENT STATUS, DESIRED OUTCOMES

For a period of over 25 years, the Malaysian economy has registered sustained growth of more than 7%, with the bulk of it attributed to the export-driven manufacturing sector. The electronics manufacturing industry in particular, supported by a strong labor force, business-friendly policies, and good physical infrastructure, has been attracting massive foreign direct investments into the country. These are excellent pre-requisites for a robust solar energy industry, and Malaysia has made substantial inroads into via partnerships with multinational solar energy corporations.

Nevertheless, in order to remain a competitive global player and fulfill its aspirations of becoming a high-income nation, Malaysia has to move up the technology value chain. This requires a critical emphasis on innovation as the fundamental driver of growth, supported by quality investments in technical talents and physical infrastructures, as well as development of niche R&D capabilities. In this chapter, we will first establish the concept of "moving up the value chain", and contend on the urgency for Malaysia to move up the value chain. The chapter then sets out to examine Malaysia's current operations along the global solar energy value chain, and identifies key opportunities and challenges.

8.1 MOVING UP THE VALUE CHAIN: CONCEPTUAL FRAMEWORK

Moving up the value chain entails shifting the activities of an entity towards those that generate higher value-added in the production of goods and services. One of the most prevailing misconceptions of moving up the value chain is to think of it as a shift in production from low-tech to high-tech goods and services. This is a flawed interpretation because how much value-added an entity generates does not necessarily correlate with the technology classification of the final products. As a case in point, Malaysia has a bigger GDP share of high-tech exports than the US, Singapore, South Korea, and Finland. Yet, Malaysia's per capita income is significantly less because Malaysia specializes in the low-cost labour and low value-added assembly operations, whereas the other said countries capitalise on providing the higher value-added and knowledge-intensive functions of R&D, engineering, branding, and marketing.

Therefore, the key for moving up the value chain depends on the amount of domestic value-added that can be generated. In other words, the crucial questions that need to be addressed in enabling Malaysia to move up the value chain are as follows: What are Malaysia's core competencies and competitive edge; and how can Malaysia generate higher value-added for the products that it currently produces?

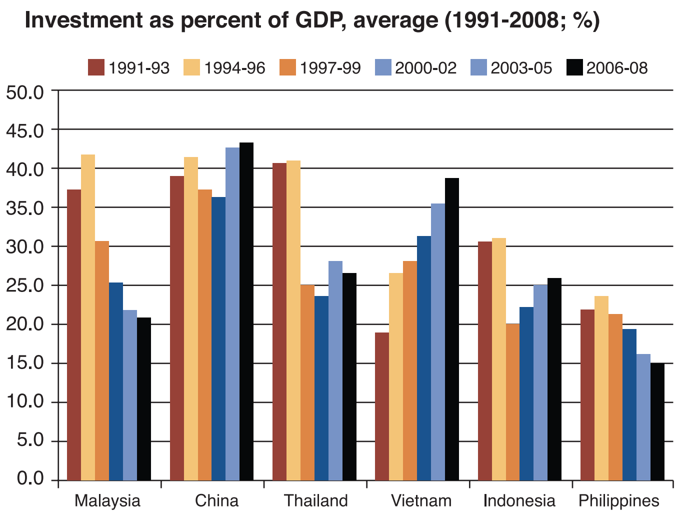


Figure 8.1 Declining foreign direct investments in Malaysia compared to several neighbouring countries

Thus, it is perhaps even more crucial to understand the underlying reasons for Malaysia to urgently move up the value chain. Malaysia's rapid industrialisation from 1980's to 2000's relied on serving as a high-vol. low-cost manufacturing hub for foreign corporations. However, the recent emergence of China, India, Vietnam, and Indonesia with a similar low-cost manufacturing model in direct competition for foreign investments is causing Malaysia's inability to remain a cost-competitive option, resulting in declining investment inflow into Malaysia compared to other neighbouring countries (**Figure 8.1**).

Malaysia is also facing difficulties to penetrate into the highly dynamic markets of knowledge-intensive products and services, hence unable to fully develop into a high-income economy, causing stagnating living standards. The challenge for Malaysia to move up the value chain will need to be met in an environment of stiff competition for investments, finite natural resources and talents — a world setting markedly different compared to three decades prior, when agrarian Malaysia first forayed into industrialisation. This further adds an element of urgency for Malaysia to develop focused strategies and effective implementations for moving up the value chain.

8.2 SOLAR ENERGY INDUSTRY SUPPLY CHAIN

The global solar PV supply chain consists of many different steps, starting from R&D and processing of raw materials down to installation of finished systems. There are two main technological pathways used for PV manufacturing, shown in **Figure 8.2**. The current dominant technology forming 75% of global market share is known as crystalline silicon solar cell technology, which is based on crystalline silicon. The silicon cell supply chain requires massive capital expenditures for specialised equipment to do casting, pulling, wafering, doping, deposition, laminating, testing, and assembling modules.

The second technological pathway is known as thin-film PV. This supply chain is relatively lower cost because the raw materials are deposited directly on a substrate, skipping a few processes and reducing the required manufacturing equipment. However, thin-film PV cells currently have lower efficiencies as compared to crystalline silicon PV cells.

Figure 8.2 also indicates other required components to support the supply chain, which include manufacturing equipment and facilities, labour, financial capital, and second level credit facilities to finance system installation. In the following sub-sections, the details of major processing steps for both supply chains are discussed, indicating the relative costs involved.

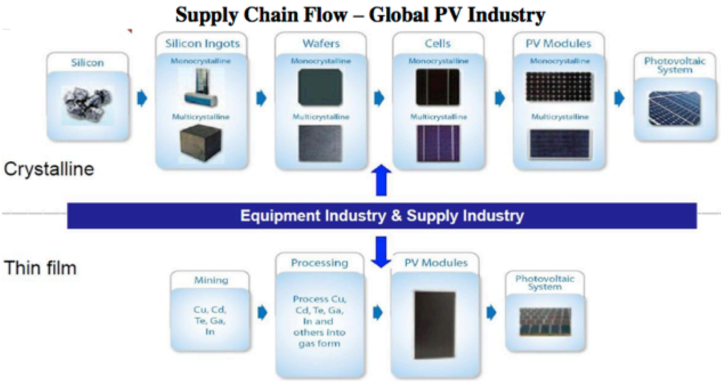


Figure 8.2 The global solar PV supply chain

Source: World Bank

8.2.1 CRYSTALLINE SILICON PV SUPPLY CHAIN

8.2.1.1 CONVERTING SAND TO SILICON

Silica (silicon dioxide) is the starting raw material for making a crystalline silicon solar cell. Silica sand is usually recovered by quarrying (**Figure 8.3**). To extract silicon, the silica must be reduced by heating it with carbon at temperatures in excess of 2,000°C. In the process, the carbon reacts with oxygen in the molten silica to produce a by-product of carbon dioxide, and metallurgical-grade silicon that is up to 99% pure. The next process is to further refine the metallurgical-grade silicon via high-temperature reactions with iron, aluminum, boron, phosphorous and hydrogen. The end product of this process is known as electronic-grade silicon and has a purity of 98.999999%.

Figure 8.3 Mining of silica for silicon extraction

8.2.1.2 GROWING SINGLE CRYSTALLINE SILICON

The electronic-grade silicon has a polycrystalline structure with structural defects called grain boundaries. These microscopic structural irregularities adversely affect electronic performance. Hence, the silicon must be turned into single crystalline structure that has a regular atomic arrangement via the Czochralski process, as shown in **Figure 8.4**. In such a high-temperature, time-consuming process, a tiny seed crystal of silicon is dipped into molten silicon and is slowly withdrawn. This causes the molten silicon to crystallise around the seed, building up a single crystalline silicon rod known as a boule with a typical diameter of 300 mm.

Figure 8.4 Industrial-scale silicon ingot growing

8.2.1.3 WAFERING

The boule is then sliced up into discs called wafers, onto which electronic components will be patterned. Slicing is done using a wire saw with slurry of silicon carbide. Next, the wafer edges are flattened, and the surfaces polished until the wafers are flat to within 2 µm.

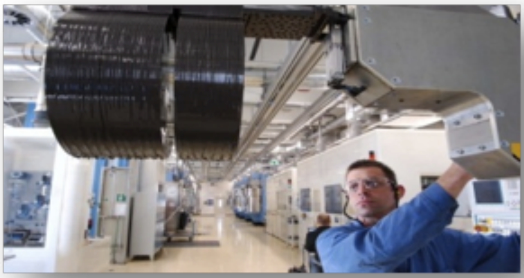


Figure 8.5 Silicon ingot slicer

8.2.1.4 DOPING OF WAFERS INTO SOLAR PHOTOVOLTAIC CELLS

To create functional photovoltaic cells, the silicon wafer has to be doped in a cleanroom facility. Doping is the process of adding impurities to the silicon wafer to create PN junctions. When exposed to light, the excited charge carriers in vicinity of the PN junctions will be driven by the built-in electric field, causing electrical current. The wafer is then coated with anti-reflective coating, screen-printed with the front and back contact, and annealed.

Figure 8.6 Doping process in a furnace to produce solar PV cells

8.2.1.5 ASSEMBLING SOLAR CELLS INTO SOLAR MODULES

The solar cells are then electrically connected together to form solar PV modules, which are then encased into weather-protective packages. After cleaning, inspection and testing, the modules are ready to be installed for power generation. Solar PV modules must comply with three centralised and worldwide standards, which are the IEC 61215, UL 1703, and Safety Class II for gird-connected modules. **Figure 8.7** shows an integrated chain of fully automated processes for assembling and testing solar PV modules, consisting ofspecialised equipment, including a cell tester, cell assembler, cell laminator and a sun simulator.

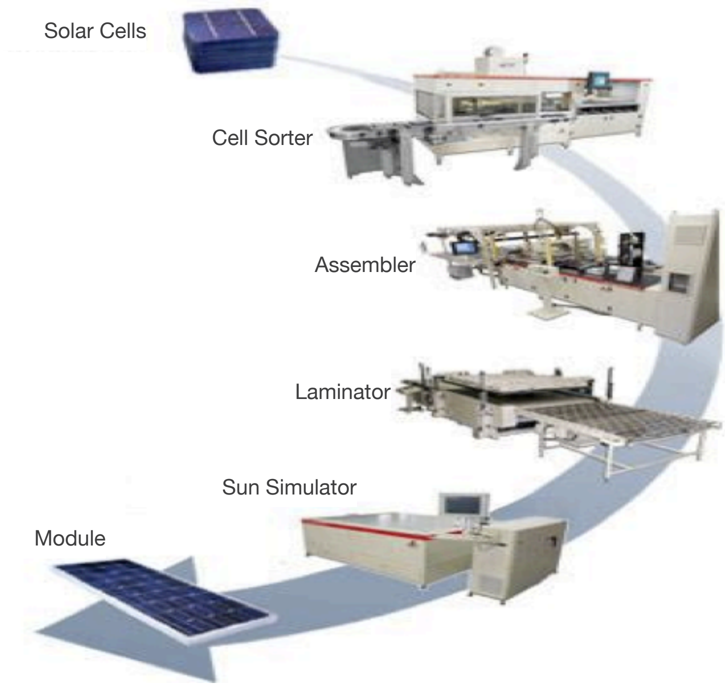


Figure 8.7 Fully-automated PV panel assembly line

Source: www.spirecorp.com

The solar cell tester acquires cell performance data in the form of current-voltage characteristics, which can be printed and stored on a disk. The solar cell assembler automatically interconnects solar cells into modules by soldering flat metal leads, or tabs, to cell contacts. The modules are then automatically laminated, before being tested using the sun simulator, which features light sources that closely match the solar spectrum while avoiding the excessive heating.

8.2.2 THIN-FILM PV SUPPLY CHAIN

The production process of thin-film PV shown in **Figure 8.1** is relatively simpler than that of crystalline silicon solar cells, hence is much cheaper. The PV materials are mined and directly deposited onto a substrate, which can either be glass, metal or plastic materials. The thin-film cells are then electrically connected to form PV modules, ready for power generation. Cadmium telluride (CdTe) is the fastest growing generation of thin-film solar cell. The toxicity of CdTe solar cells has been widely discussed among experts, as Cd is a heavy metal cumulative poison. However, as part of amorphous silicon, it can be delivered on a larger scale.

8.2.3 SOLAR THERMAL SYSTEMS SUPPLY CHAIN

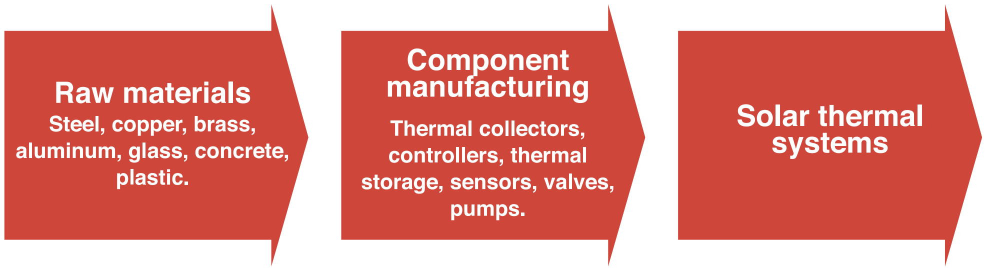


Figure 8.8 Solar thermal systems supply chain

In the solar thermal systems supply chain shown in **Figure 8.8**, the required raw materials include metals such as steel, copper, brass, and aluminum, along with glass, plastic and concrete — most of which can be locally sourced. These are processed to manufacture the integral components of solar thermal systems, which are thermal collectors, controllers, thermal storage and tanks, sensors, framing, pumps, valves and tubes. The main sub-components of flat-plate solar thermal collectors the glass cover, insulation, the metal container, and absorber made from metal or polymers. The absorber is usually coated with selective surface materials for enhanced solar absorption while minimising heat loss. Extruded aluminum profiles, galvanised steel, stainless steel, and low iron glass are off-the-shelf products. Aluminum for the framing has to be anodised for installations in tropical conditions. The finished components are then integrated into a complete solar thermal system, ready to be installed at power-generating sites.

8.3 MALAYSIA'S OPERATIONS ON THE SOLAR ENERGY INDUSTRY VALUE CHAIN

The solar energy industry value chain, along with indication of relative quantum of value-added along the chain is shown in **Figure 8.9**. The value chain can be divided into two parts: upstream and downstream. The upstream part begins from the relatively highest value-added R&D down to the lowest value-added of PV module assembly operations. The downstream part begins from the low value-added system integration and installation operations up to the high value-added support services.

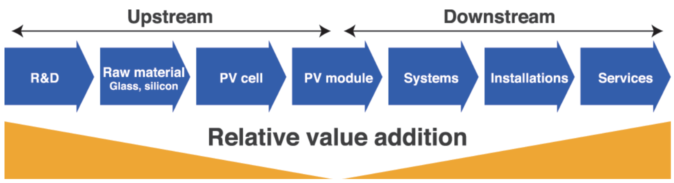


Figure 8.9 Solar energy technology value chain

Thus, in order for Malaysia to move up the technology value chain, it should begin capitalising on the operations that generate high proportions of value-added on the value chain. These include R&D and raw material processing in the upstream operations, and downstream system installation and services. As a case in point, in the upstream part of the chain, the largest cost component (of nearly 30%) of a solar cell that is sold for USD 1.50/watt (2009 price) is raw materials (polysilicon). The same solar cell would be worth USD 2.50/watt when assembled into a solar module, and worth close to USD 5.50/watt when installed at the generating site. Hence, there is nearly USD 4/watt worth of value-added generated in the downstream operations of installation and services. Nevertheless, no Malaysian company currently produces and processes the feedstock (glass and silicon), and only a small number of Malaysian companies specialise in the skill-intensive upstream PV manufacturing and downstream services.

Table 8.1 Multinational PV manufacturers operating in Malaysia

Company	Location	Products	Annual capacity	Employees	Operating since
First Solar (US)	Kulim	Thin-film modules	1,500 MW	3,500	2008
Q-Cells (Germany)	Selangor	Crystalline silicon ingots, wafers and cells.	800 MW	3,500	2009
Sunpower (US/ Taiwan)	Rembia, Melaka	Crystalline silicon ingots, wafers and cells.	1,500 MW	5,500	2010
Tokuyama (Japan)	Bintulu	Polysilicon	3,000 metric ton	500	2011
Twin Creeks (US)	Ipoh	Crystalline silicon cells and modules	500 MW	NA	2012

Source: World Bank

Malaysia has committed massive investments to attract some of the world's most advanced solar PV firms from a range of technologies (**Table 8.1**) to set up manufacturing plants in Malaysia, collectively employing more than 10,000 local workers and creating a variety of next-door business opportunities to local industries. These multinational solar PV corporations include First Solar, Sunpower, Q-Cells, and Twin Creek Technologies.

Malaysia has also partnered with Tokuyama in setting up a polysilicon processing plant in Bintulu, Sarawak. Collectively, these firms operate from the beginning of the value chain (raw materials) down to fabrication of PV cells and thin-film modules only (**Figure 8.10**), after which the finished products are exported out of Malaysia for module assembly, integration and installations. Arguably, the primary incentive for them to set up manufacturing plants in Malaysia is the low-cost local labour, enabling them to remain cost-competitive while maintaining their higher value-added R&D and service operations in their home base.

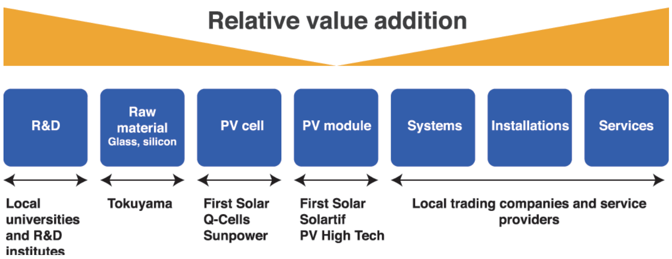


Figure 8.10 Solar PV firms' operational positions along the solar energy value chain in Malaysia. Malaysian operations are currently limited to R&D, and to downstream system installation and services

Despite having Malaysian R&D operations in the upstream part of the value chain, currently only a small number of Malaysian companies manufacture its own brand of solar PV and thermal systems on an industrial scale (**Table 8.2**), and no Malaysian organisation that produce glass and silicon, which are high value-added feedstock components of the value chain. As a result of this disconnectedness, the high value-added generated by Malaysian R&D operations are not fully and efficiently trickled down to commercial scale PV manufacturing. In addition, the downstream Malaysian trading companies and service providers also have to depend on externally generated value-added (in the form of imported PV systems) that increase their business costs.

Table 8.2 Malaysian solar thermal and PV manufacturers

Product type	Malaysian manufacturer
Solar thermal system components	1. Solar Tech Sdn Bhd 2. Microsolar 3. Solarmate Sdn Bhd
Solar PV cell and module	1. Solartif Sdn Bhd 2. PV High Tech Sdn Bhd 3. Malaysian Solar Resources Sdn Bhd 4. TS Solar Tech Sdn Bhd 5. HBE Gratings Sdn Bhd

Therefore, the study team is of the opinion that as far as the value chain is concerned, Malaysia has already rightly positioned itself at the high value-added operations along the chain (e.g. R&D on the upstream, and services on the downstream). What must be done for Malaysia to fully develop and participate along the *entire* value chain are the following:

1) ***Connect the tail-ends of the value chain*** by setting up Malaysia's very own silicon feedstock producers; and increasing the number of Malaysian PV manufacturers. This would enable layer upon layer of value-added to be collectively built upon by Malaysian firms — starting with technology input by Malaysian R&D to locally sourced silicon and glass, processed into complete PV systems by Malaysian manufacturers. The resulting cost advantage would result in competitively priced Malaysian-made PV systems for local and export market.

2) ***Grow the number of local industry players*** supporting every operation along the value chain, which include components manufacturing, equipment services, transportations, credit facilities and product services. This will enlarge the local market for Malaysian-made solar PV systems and contribute towards achieving grid-parity.

8.3.1 OPPORTUNITIES FOR MALAYSIA

8.3.1.1 CUTTING EDGE R&D AND TECHNOLOGY COMMERCIALISATION

R&D is the most knowledge-intensive, highest value-added component in the solar energy value chain, requiring massive human and physical capital. Product differentiation and acceptance strongly depend on competent R&D efforts. Globally competing firms invest substantial proportions of revenues back into R&D in order to stay ahead of competition. The pay-offs of successful R&D include innovative products, market dominance, costs reduction and intangibles such as branding, all of which may be worth well more the R&D investments made.

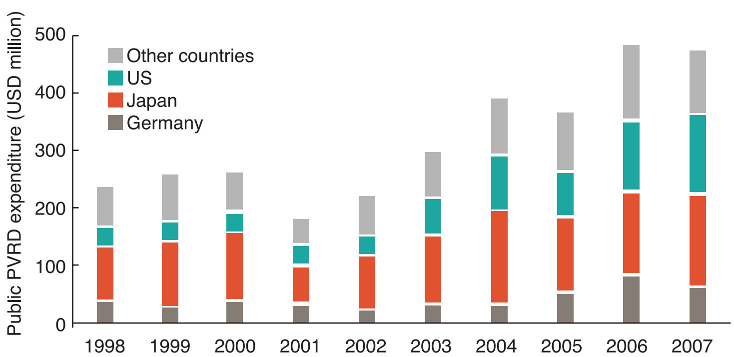


Figure 8.11 Worldwide R&D expenditures on solar PV

Source: IEA PVS

Worldwide R&D expenditures on solar PV have doubled over a decade, rising from USD 250 million in the year 2000 to USD 500 million in 2007, with the bulk of it coming from Japan, US and Germany (**Figure 8.11**). It is therefore not a coincidence that the same countries are also global leaders in the solar energy market. Therefore, intensifying and capitalising Malaysia's R&D capabilities could be the single most important key for Malaysia to move up the technology value chain of solar energy.

Furthermore, foreign PV manufacturers operating in Malaysia often have with their own in-house R&D, leaving very little room for appropriating additional value-added to Malaysian firms. This is because the foreign MNCs are concerned about guarding their intellectual properties, and are hence reluctant to share them with local counterparts. One possible way to capitalise on Malaysia's R&D output is through technology licensing to local and foreign PV manufacturers, which can be facilitated via enhanced collaborations between researchers and venture capitalists. The other way is to offer outsourcing R&D services to PV firms — these include yield optimisation, market research, engineering and business consultancies.

8.3.1.2 UPSTREAM COMPONENTS PROCESSING OF GLASS AND POLYSILICON

PV manufacturers are under constant pressure to drive costs down, the bulk of which come from raw materials. To capture this high value-added input of the upstream part of the value chain, Malaysia should commit more investment to setting up facilities for glass and polysilicon processing. Despite the massive capital required, this will in turn serve the dual purpose of increasing the pool of economic value-added available to the Malaysian economy, and making Malaysia more attractive for multinational and local PV firms to establish and retain their PV manufacturing facilities.

8.3.1.3 PV CELL AND MODULE MANUFACTURING

Considering Malaysia's well-established experience in the technically similar electronics manufacturing industry since the 1980's, and supported by local solar energy R&D, Malaysia is technically ready to design and manufacture its very own brand of PV cells and modules on a bigger scale. This would also in effect connect the high value-added tail-ends of the chain (R&D, services) at which Malaysian firms already have some operations: the end result is Malaysia would be able to own up the *entire* technology value chain. The multiplier effects are numerous, including job creations, formation of satellite SMEs, increased national trade, and Malaysian branding, potentially transforming the local solar energy sector into a major national industry.

8.4.1.4 DOWNSTREAM COMPONENTS MANUFACTURING

PV manufacturers also have requirements for additional consumables (such as laminates, tabbing and stringing, and so on), which may already be available because of the electronics industry already established in Malaysia. In addition, PV system installations require components such as inverters, charge regulators, aluminium frames, plastics, EVAs, and junction boxes. These inputs to the downstream part can provide profitable opportunities for local manufacturing companies.

8.4.1.5 DOWNSTREAM INSTALLATION AND SERVICES

World Bank data suggests that there is a tremendous amount of value-added available in the installation and product services of PV systems for domestic consumption. These include labour, logistics, waste management, and business processes that far exceed the amount available in intermediate steps of module manufacturing. To date, only a small fraction of this downstream value-added is captured by Malaysia. However, the key requisite for profitable ventures in this downstream part of the value chain is a sustainably high vol. of domestic PV installations to drive the demands for services.

8.3.2 CHALLENGES

8.3.2.1 UNDER-DEVELOPED DOMESTIC MARKET FOR SOLAR POWER

As of early 2014, Malaysia has solar PV cumulative capacity of 88 MW, generating more than 45 GWh power annually. This provides a very small percentage contribution to total domestic electricity demand, indicating Malaysia's relatively under-developed domestic solar PV market compared to neighbouring countries such as Thailand, India, and China (**Figure 8.52**). A strong public sentiment prevailing in Malaysia is that solar energy is an expensive exotic technology only useful for limited commercial applications and research purposes. This belief, substantiated or not, is a major hindrance to driving costs down towards achieving grid parity.

8.3.2.2 LIMITED FINANCING FACILITIES FOR PV INSTALLATIONS

A substantial capital is required for PV installation; in effect, consumers are actually paying up-front electricity costs upon PV system installation. Nevertheless, PV installation provides a stable income stream that can be used to support the required credit of capital investment. However, local banks are currently not familiar with the technology and associated risks, hence their aversion to provide this type of capital.

8.3.2.3 GOVERNANCE AND REGULATORY ISSUES

The development of RE in Malaysia is hampered by the following regulatory shortcomings:

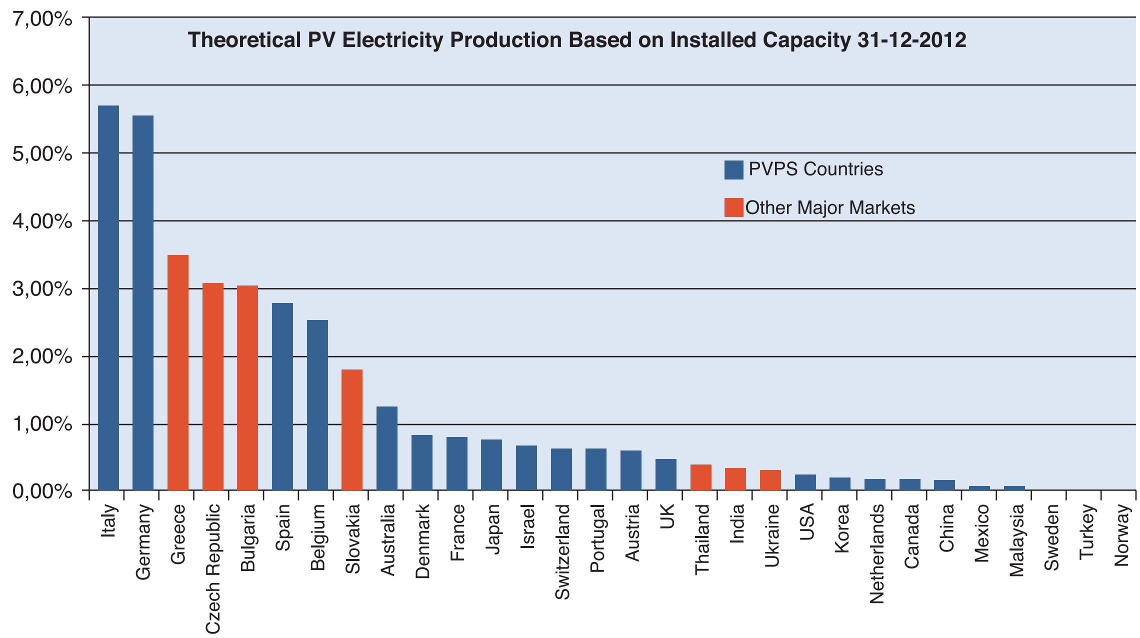


Figure 8.12 PV power contribution to electricity demand in several countries

Note: Indicates Malaysia's underdeveloped domestic market for solar PV.

Source: IEA-PVPS 2013

- Limited access to the national grid and FIT quota, creating a situation of monopsony (many sellers to one buyer)
- Massive government subsidies extend public reliance and consumption of fossil fuels
- Absence of carbon-tax mechanism (penalty for carbon dioxide emission) applied to power producers, industries and the general public makes fossil fuels a naturallypreferred power source
- Difficulty in obtaining planning permissions and environmental licensing from the authorities to set up reinstallations
- General lack of strategised publicity drive to increase awareness and encourage investments in RE
- Long period of investment payback.

8.4 RECOMMENDATIONS TO DEVELOP MALAYSIA'S VALUE CHAIN

In 2011, the World Bank released a report entitled "Moving up the value chain: A study of Malaysia's solar and medical device industries", encouraging Malaysia focus its manufacturing resources on downstream activities as a strategy for generating more value-added, leaving the high value-added components of the upstream operations to countries with more established solar energy industry. A response to the World Bank report published by Bakhtyar questions the validity of the methods and assumptions of the World Bank study which allegedly leads to the lack of reliability of the report's recommended strategy, implemented. Its might decrease the security of future investments in Malaysia, raise the final price of products, and create industry crisis in the event of market imbalance. Based on Malaysia's current status, combined with stakeholders' feedback from the industry, we recommend the following actions for Malaysia to develop and capitalise on its operations along the global solar energy industry value chain:

8.4.1 ESTABLISH A SILICON FEEDSTOCK PROCESSING INDUSTRY IN MALAYSIA

Silicon and glass are the largest cost component in the manufacturing of solar PV cells. However, there is currently no Malaysian firm that processes these high value-added feedstock, despite the availability of high-grade silica sand in Malaysia, low technological barriers of entry, and globally growing demands. Even though massive capital outlay is required, investments into the silicon and glass processing ventures can be recouped within a relatively short time frame due to the wide-ranging demands from the electronics industry, in addition to growing demands from global solar PV manufacturers. Locally-sourced silicon feedstock would also present a significant cost advantage for a proposed silicon ingot production industry in Malaysia, and for local PV manufacturing operations along the entire value-chain.

8.4.2 PRODUCTION OF SILICON INGOT IN MALAYSIA

Over 90% of solar cells produced worldwide are currently based on crystalline silicon wafers which are expected to dominate the market over the next 10 years. This growing demand presents an immediate opportunity for the Malaysian Government to invest into the silicon ingot production industry, which can be targeted to be operational by as early as next year (2015) due to low technical barriers for entry. Standard production equipments for industrial-scale ingot-growing can be bought off the shelf. Potential collaborators for this venture include the SERI of UKM, which is a well-established local R&D institute; and PV Crystalox Solar, one of the world's largest independent producer of silicon ingot.

8.4.3 STRATEGIC COORDINATION OF R&D AND TECHNOLOGY COMMERCIALISATION

Developing R&D capabilities involve an extensive period of time and massive investments. Nevertheless, fortunately the necessary seed steps have already been undertaken by the Malaysian Government via setting up of more than a dozen of solar energy research institutes and related facilities, allocation of research funds, and training of research personnel. We propose the following strategies to promote and capitalise on local R&D capabilities:

- Commit GLC investments into rapid-prototyping of advanced and promising PV technologies produced by local universities, and catalyse the creation spin-off technology companies;
- Establish a national Centre of Excellence for Solar Energy to strategise and coordinate all the solar energy research programs currently carried out in more than a dozen of R&D centres in the country. Such a centre can also provide related training and support, and function as a one-stop reference point for investors and interested public;
- Develop and capitalise on niche R&D expertise, such as improving PV efficiencies in tropical regions like Malaysia where the solar radiation is diffused; and
- Increase R&D budget for next-generation high-performance PV technologies, safer and cheaper processes, nano-structured solar cells, and novel materials.

8.4.4 POLICY REFINEMENT, GOVERNANCE IMPROVEMENT AND EFFECTIVE PUBLICITY DRIVE

- Refine the FiT scheme by increasing the quota with easier and fairer access to satisfy the market demand;
- Spur domestic demand by mandating RE-friendly policies, such as that all government buildings must be equipped with solar energy harvesting capabilities;
- Provide tax incentives for property developers that incorporate solar energy systems in their developments;
- Implement effective advocacy programs to raise public awareness;
- Introduce carbon-tax to penalise polluters and promote efficient production and consumption of energy;
- Reduce the government subsidies for fossil fuels to encourage public preference of renewable energies;
- Active coordination of various government agencies to promote solar energy; and
- Provide financing facilities with reasonable quantum of subsidies to promote domestic installations of solar PV.

8.4.5 DEVELOP A CONDUCIVE BUSINESS ECOSYSTEM FOR GREEN SMES

- Introduce business facilitation packages that include soft loans, focus grants, industry missions for local investors;
- Develop a Green-Industry Zone, adapted from Penang's Free Industrial Zone, to promote investments and trade related to renewable energies where investors are attracted with minimal formalities and taxes; and
- Provide convenience in granting permissions and licenses for solar energy installations.

8.5 HIGH POTENTIAL APPLICATIONS OF SOLAR ENERGY IN MALAYSIA

8.5.1 SOLAR WATER HEATING FOR PUBLIC HOSPITALS NATIONWIDE

One of the most economically attractive and immediate applications of solar heating is in the public healthcare system. In a case study funded by the Ministry of Science, Technology and Innovation (MOSTI) carried out at the Hospital Universiti Kebangsaan Malaysia

(HUKM), the solar water heating employed to replace the conventional LPG boilers results in a massive 50% LPG savings of 29,000 kg/year with approximately CO_2 reduction of 64,000 kg/year. An estimated market potential worth over RM200 million exists for the system to be deployed nationwide to a prospect of 135 Government hospitals.

Figure 8.13 Solar hot water heating system for hospitals

8.5.2 POVERTY REDUCTION VIA TARGETED FIT POLICY AND CSR SPONSORSHIP OF SOLAR PANELS

About 5% of Malaysian households earn less than RM1, 000 per month, an income bracket that lies very near to the national poverty line. Under a special quota allocation of the FiT scheme targeted for the poor, these low-income households will stand to earn additional income of RM300 to RM500 per month when sponsored solar panels are installed at their houses. The corporate sponsorships of the solar panels can be wooed with tax credits and other reasonable incentives. The installations and post-sales services of the solar panels can also create jobs and next-door business opportunities which can be filled by the targeted communities themselves, thus further alleviating their socio-economic standing.

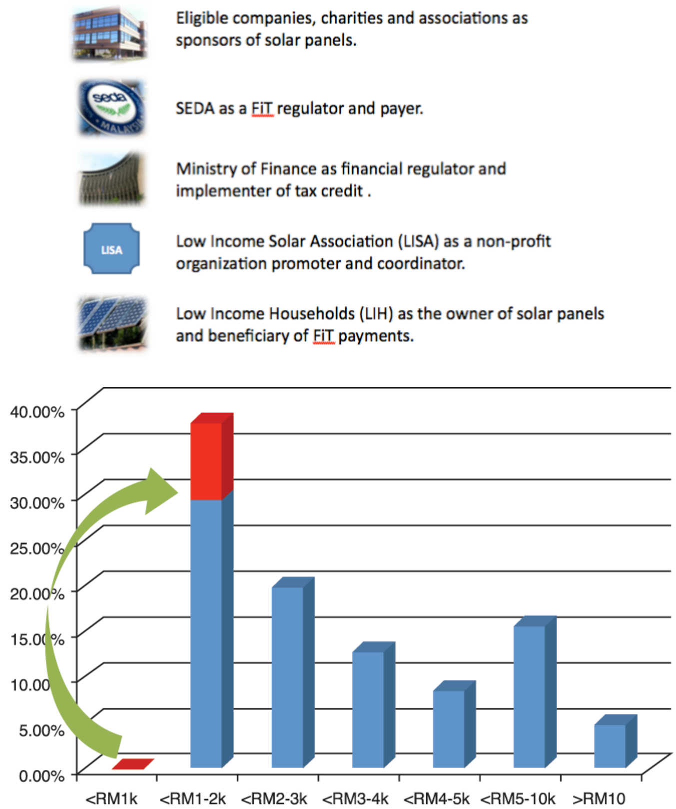


Figure 8.14 Top: The Key partners for the special initiative of poverty reduction usin targeted FiT scheme and corporate sponsorships of solar panels

Bottom: The potential additional income will shift the targeted poor households (earning less than RM1,000 per month) to a higher income bracket

The framework for this poverty reduction initiative is shown in **Figure 8.15**. SEDA as the FiT regulator allocates a special quota for the targeted poor households, and LISA as the initiative coordinator that identifies eligible households and registers the corporate sponsors with the Ministry of Finance, which then implements tax credits to the sponsors upon solar panel installations. The targeted low-income households as the owners of the sponsored solar panels are responsible for the basic maintenance of the solar panels. The electricity generated by the solar panels are sold to SEDA under the allocated quota, and SEDA then disburses the payments back to the poor households for the purchased amount of electricity.

8.5.3 SOLAR PROCESS HEAT TO BOOST MALAYSIA'S AGRICULTURAL AND FISHERY SECTORS

The agricultural sector contributes up to 12% of Malaysia's GDP, in which the post-harvest drying process is important to extend the commodity shelf life. Although solar-drying technology is technically simple, its take up rate is very low compared to diesel-powered dryers or traditional sun drying.

Solar-drying can offer significant cost savings compared to the diesel-powered dryers which are subjected to escalating fuel prices. In addition, typical solar-drying systems are also simple enough for rapid deployment with a typical payback period of two to three years, while also offering higher efficiencies compared to the traditional sun drying. Examples of potential applications include solar-drying for oil palm fronds, cocoa, anchovies and seaweeds; and solar-assisted air conditioning for aquaphonic systems for the simultaneous production of foods and energy.

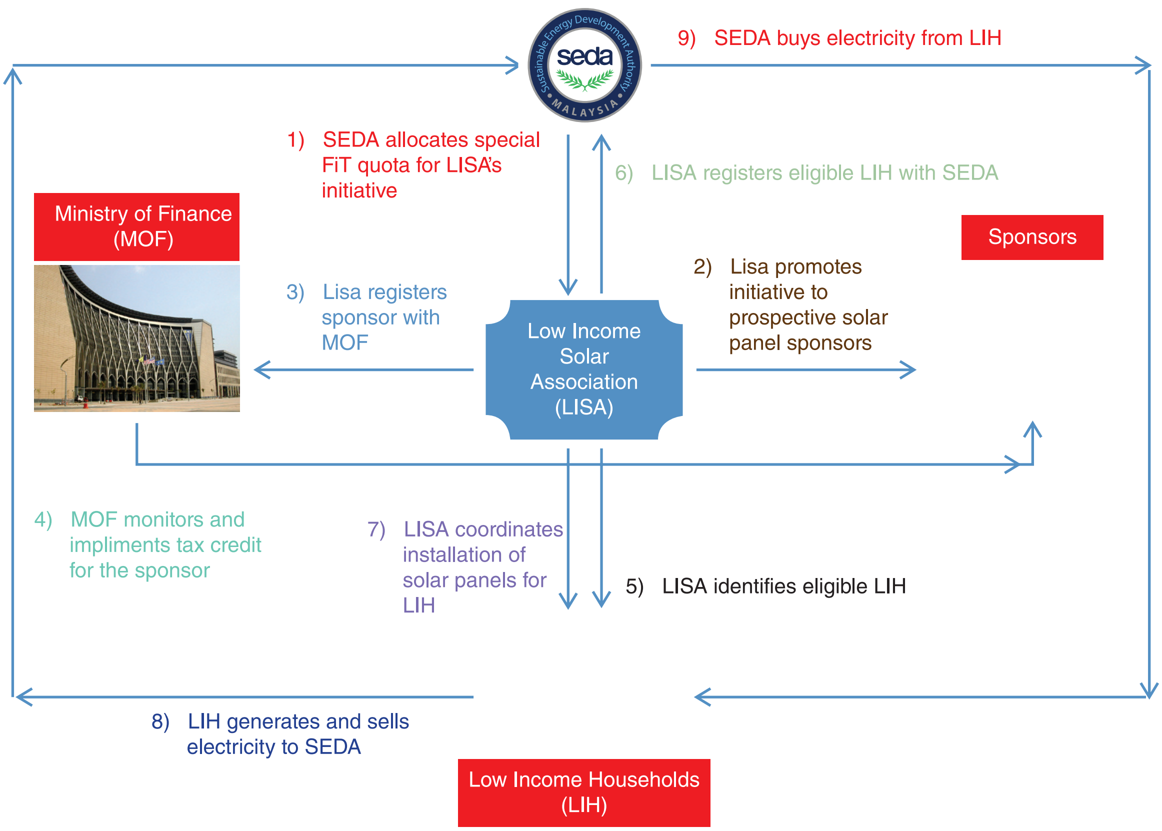


Figure 8.15 The proposed framework of poverty reduction using targeted FiT scheme and corporate sponsorships of solar panels

Figure 8.16 Solar drying system for agricultural and marine products

8.5.4 NET ZERO-ENERGY GOVERNMENT OFFICE BUILDINGS FOR REDUCED ENERGY EXPENDITURES

A net zero-energy building is a building with zero or very-low net consumption of energy. In other words, the total amount of energy needed by the building is met by the renewable energies self-generated on the site of the building itself. This is achieved via incorporation of a range of energy efficiency measures and features into the holistic design of the building, which include building-integrated photovoltaics, natural lighting and ventilation, high-efficiency electrical equipments, high-performance thermal insulation, and proper building orientation relative to the sun's position.

The substantially higher costs of building construction are offset by the significantly reduced costs of ownership due to improved energy efficiencies. Net zero-energy buildings also have higher resale values, and are also insulated against the effects of energy price fluctuations. These advantages can be significantly scaled up with the implementation of net zero-energy building for future developments of government offices. A landmark example of a net zero–energy building in Malaysia is PTM.

Figure 8.17 Among the energy-efficient measures (solar panels, natural lighting) of the net zero-energy office building of Pusat Tenaga Malaysia

8.6 CONCLUSION

The study team has provided the case for Malaysia to urgently move up the technology value chain in order to develop into a high-income economy, counteracting the adverse effects of declining FDIs. Malaysian operations on the solar energy industry value chain are currently disconnected, limited only to the upstream R&D and downstream installation services, whereas the feedstock (glass, silicon) processing, and PV manufacturing are mainly done by foreign corporations. Thus, the high value-added generated by Malaysian R&D operations are not fully trickled down to PV manufacturing and system installations.

We recommend setting up Malaysian corporations for the production and processing of silicon feedstock, and increasing the number of Malaysian PV and related components manufacturers. This can be done by introducing a business facilitation package to local SMEs, in addition of intensification of R&D commercialisation via GLC investments and incubator programs for rapid spin-offs. Malaysia's underdeveloped domestic market for solar energy systems is a major stumbling block to developing a local solar energy industry, which must be addressed via feed-in-tariff refinements and enforcement of market stimulants such as publicity drives, easy financing, carbon taxes, and RE-friendly regulations.

CHAPTER 9

SOLAR AS AN EFFICIENT RENEWABLE ENERGY - BASELINE STUDY: GLOBAL DRIVERS,TECHNOLOGY OVERVIEW, CASE STUDIES, MARKET TREND, MALAYSIA'S CURRENT STATUS, DESIRED OUTCOMES

9.1 PURPOSE OF THE ROADMAP

This roadmap is prepared with the primary objective of providing the basis for a focused government-industry-academia collaborations on a set of identified technological, economic and policy action plans, aimed at driving the Malaysian solar energy industry towards sustainable growth and competitiveness. Accordingly, the recommended action plans in this roadmap are divided into short-, medium- and long-term strategies with assigned stakeholders. This roadmap should be regarded as dynamic blueprint rather than a cast-in-stone set of instructions. The milestone dates are indicative of relative urgency and priority rather than as absolutes.

9.2 SCOPE AND STRUCTURE

This roadmap covers four dimensions of change for long-term growth and sustainability of Malaysian solar energy industry, which are as follows:

a) R&D

b) Institutional framework and policies

c) Infrastructure development

d) Value chain and market development

9.3 ROADMAP METHODOLOGY

The primary approach employed in preparing this roadmap was backcasting, informed with stakeholders input (a stakeholders workshop was organised on 5th February, 2014 at the ASM to pool ideas and feedback from regulatory agencies, industry and academia). For the purpose of developing this roadmap, the specific technical focus areas for solar energy applications in Malaysia were first identified. Then, the desired future scenario was first envisioned by scenario-building. By working backwards to the present time, the required specific actions and stakeholders were then identified in order to attain the desired future outcomes. The resulting action plan, strategised into short-to-long-term measures, covers the four change dimensions of R&D, Policies, Infrastructure, and Value Chain.

9.4 ACTION PLAN FOR MALAYSIA'S SOLAR PHOTOVOLTAIC\INDUSTRY

9.4.1 SHORT-TERM ACTION PLAN (2015 – 2020)

Solar Energy Transformed into a Major National Industry

The desired near-term scenario is Malaysia having a robust local solar energy industry that self-sufficiently generates value-added on every operation along the entire value chain. The transformation of solar energy into a major national industry can be realistically accomplished within 5 years' time. The key elements required to realise this envisioned near-term scenario are having a local solar energy market of sufficient critical mass to drive demands, and establishing Malaysian solar PV manufacturers that can capitalise on local R&D and sourcing from Malaysian produced silicon feedstock.

Hence, there is an urgent need for Malaysian economic planners to develop and take ownership of this energy sector, not only for the benefit staying competitive, but also with the aim for Malaysia to be in the league of regional and global leaders of renewable energies. Hence, the entire supply chain of the silicon solar cell industry — beginning from the capabilities to purify silicon, grow ingots, wafer processing, solar cells manufacturing and panel assembly — must be established in the short term. This can be done in 2 phases: silicon wafer growth in the first phase in 2015,

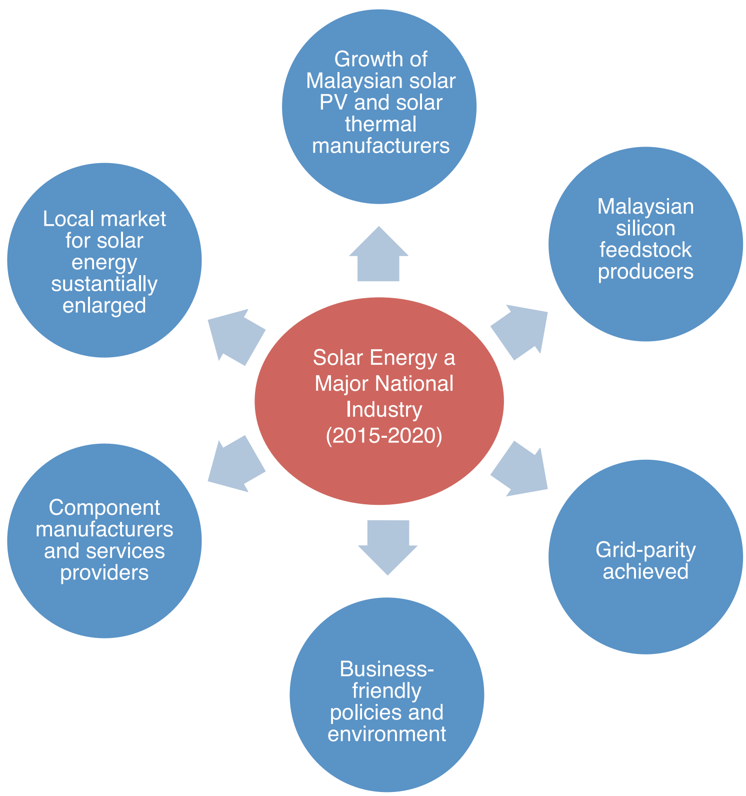


Figure 9.1 The desired near-term scenario for Malaysia's solar energy industry

and silicon purification in the second phase in 2018. The committed investments will pay off in a short time considering the spillover applications of this technology in Malaysia's well-established Integrated-Circuit (IC) fabrication industry.

Another important aspect in the short-term plan is to produce solar cell that uses less water and non-toxic materials. Excessive water use in PV manufacturing brings negative impact on environment. In silicon PV technologies, it has been estimated that 1 million gallons of water is used for each MW of production; this figures includes all PV technology sectors. Extensive research efforts aimed at recycling, reduction of water usage, and in some cases - its complete elimination in the process loop, will help make silicon PV technologies more environment-friendly. In addition, the substitution of explosive materials such as silane that are used as anti-reflective coating for solar cells should be investigated.

Table 9.1 Short-term action plan (2015-2020) for Malaysia's solar energy industry

Change dimensions	Actions	Stakeholders	Desired outcomes
R&D	1. Develop thin crystalline silicon cell (<50 um) technology. Improve wet-texturing and ingot-producing processes to reduce material costs. Improve passivation technique to reduce cell cost 2. Develop single and multi-junction thin-film a-Si solar cells with interface layers, tunnel junctions, anti-reflection coating and back-reflector 3. Efficiency improvement of thin-film solar cells 4. Undertake studies on charge transport in nano-crystalline solar cells and other novel devices to stay competitive in advanced technologies. Produce lab-scale prototype devices	MOSTI, scientists, researchers, process engineers, universities, technology investors	1. Thinner silicon wafer technology. 2. Improved performance and processing. 3. Advanced integration and packaging. 4. Low cost silicon feedstock. 5. Hybrid solar

Institutional framework and policies	1. Concerted and consistent publicity drive by relevant authorities on clean energies and energy-efficient lifestyle to raise public awareness 2. Implement market-intervention measures to stimulate local demands. E.g. Tax relief for local PV manufacturers; mandating all new government buildings be equipped solar energy systems 3. Offer financial incentives (e.g. tax breaks) for property developers to incorporate solar energy harvesting capabilities in commercial and residential buildings 4. Refine the feed-in-tariffs to yield shorter payback period, provide easy access to national grid and quota to spur investments in solar energy 5. Increase funding for R&D in advanced solar energy technologies 6. Introduce carbon-tax to promote renewable energy resources 7. Reduce subsidies of fossil fuel to exert real market pressure on consumption 8. Stronger emphasis on Science and Technology in all levels of national education 9. Develop and implement energy-efficiency benchmarks for power producers (with penalties for underachievers) to optimise resources 10. Develop and implement safety regulations for all types of solar energy installations	MOSTI, PEMANDU, EPU, TNB, private generators	1. Dramatic jump in local demands for solar PV and thermal installations 2. 10% of total electricity demand is by renewable resources 3. Creation of skilled and semi-skilled jobs in solar energy industry 4. Grid-parity nearly or fully achieved

Infrastructure	1. Develop green-industry zones with easy access to transportations, communications, utilities and human resource 2. Establish training centres and programmes for skilled and semi-skilled workers in solar energy industry 3. Ensure reliable supply of electricity and basic utilities to industrial zones	MITI, universities, colleges	1. A self-sustaining ecosystem of local solar energy industry
Value chain and market development	1. Expand current partnerships with foreign PV manufacturers to include module integration and product services. Provide incentives for technology transfers 2. Set up Malaysian silicon and glass producers to cater for global feedstock demands in solar energy industry 3. Set up Malaysian PV cell manufacturers and module assemblers, sourcing from locally sourced silicon and glass by Malaysian producers 4. Large-scale commercialisation drive of local R&D output via University-Industry-Government partnerships 5. Commit GLC investments to promising new technologies by developed by Malaysian R&D, and catalyse the growth of rapid spin-off companies	MITI, private investors, start-up companies	1. Designed-and-made in Malaysia PV cells, modules and systems 2. Malaysian-owned glass and polysilicon processing plants 3. Existing solar MNCs expanding operations into system integration and installation

9.4.2 MEDIUM-TERM ACTION PLAN (2021 – 2035)

Global Expansion of Malaysian Solar Energy Industry

The desired medium-term scenario is the global expansion of Malaysian market share of solar energy systems, where it is envisioned that Malaysian solar energy conglomerates will be among the world's top-10 producers, backed by a robust domestic market that has achieved the point of grid-parity. Within the same time frame, Malaysian solar energy R&D is targeted to be at the forefront in advanced-generation solar energy technologies.

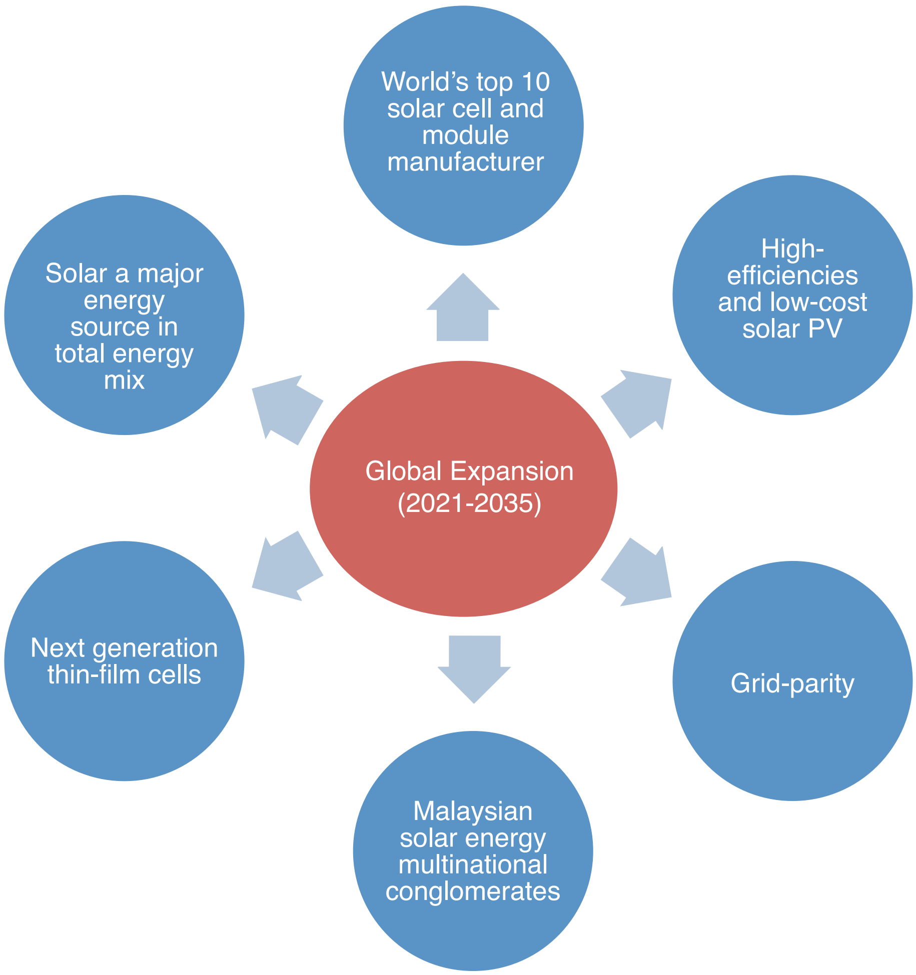


Figure 9.2 The medium-term desired scenario of Malaysia's global expansion in solar energy industry

The medium-term action plan for the Malaysian PV industry is technology-driven. These would include breakthrough cell efficiencies exceeding 25%, the use of concentrators, organics solar cells, silicon cell of less than 50 microns, and thin-films technologies. Beyond the year 2020, the global solar energy market is expected to be technology-driven.

Furthermore, market growth is expected to reach saturation point in many developed countries following attainment of domestic grid-parity, and also because of the long operational lifetimes of solar energy installations. This will in turn create an expected global surge of demand for product services. Accordingly, the R&D focus is expected to be on improving module efficiencies and manufacturing processes, as well as on advanced technologies involving nano-structures and nano-materials. The market is expected to continue to grow in many developing countries, which presents trade potential for Malaysia.

Table 9.2 Medium-term action plan (2021-2035) for Malaysia’s solar energy industry

Change dimensions	Actions	Stakeholders	Desired outcomes
R&D	1. Develop chemical-free, faster, safer and cheaper texturing processes 2. Development of hetero intrinsic a-Si and micro-nanocrystalline film 3. Increase thin-film cell efficiency and technology lifetime with new electrodes and materials 4. Studies on nanostructured solar cells	Scientists, researchers, process engineers, universities, MOSTI	1. Increased thin film efficiency from 11%-40% 2. Lowest possible cost of silicon cells
Institutional framework and policies	1. International agreements to increase bilateral trades with developing markets 2. Share increase of renewable resources in electricity generation 3. Mandating that property developers in incorporate solar energy systems in buildings, residential parks and townships 4. Increase funding for R&D in future solar cell technologies	MITI, PEMANDU, EPU	1. Increased international trade in solar energy sector 2. Sustained demands for domestic solar PV installations and services 3. 25% of total electricity demand is met by renewable resources

Infrastructure	Large-scale developments of BIPV and solar-energy farms to sustain grid parity	Property developers, technology owners, local authorities	Continued growth up of local SMEs in the business exporting components and packaged services
Value chain and market development	1. International agreements to increase trades with developing markets 2. Commercialisation of nano-cell technologies 3. Intensification of Malaysian R&D branding and commercialisation	MITI, private investors, angel investors, start up companies	1. Malaysian solar energy conglomerates with global presence, from R&D to product services 2. Malaysian PV manufacturers attaining top-10 world market share

9.4.3 LONG-TERM ACTION PLAN (2035 – 2050)

Malaysia as a Global Solar Energy Powerhouse

The long-term action-plan for Malaysian PV industry is mainly research-driven, focusing on nanotechnology, organics and bio-inspired solar cells, quantum dots, and multi-multi junction cells. Thelong-term desired scenario is having Malaysia as a solar energy R&D powerhouse, producing world's top-10 R&D output and novel solar energy systems, such quantum solar cells and solar-energy harvesters in outer space. Fossil fuels are expected to be fully-phased out in the domestic energy-mix, replaced by solar energy sources.

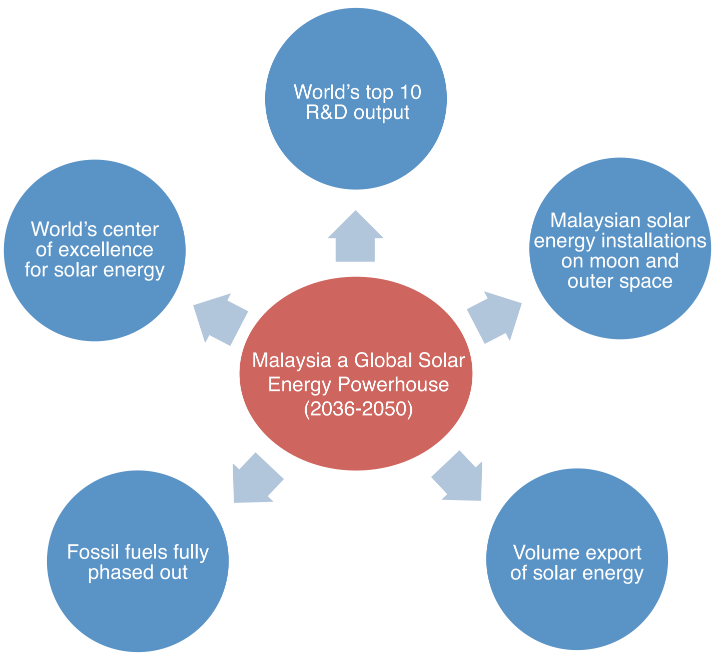


Figure 9.3 The long-term desired scenario of Malaysia's solar energy industry

Table 9.3 Long-term action plan (2035-2050) for Malaysia's solar energy sector

Change dimensions	Actions	Stakeholders	Desired outcomes
R&D	Development and commercialisation of novel solar cell technologies, utilising quantum structures and synthetic bio-inspired materials	Scientists, researchers, process engineers, universities, MOSTI	Malaysia becoming a global R&D powerhouse
Institutional framework and policies	1. Continued domestic enlargement of the share of renewable resources in electricity generation 2. Increase funding for R&D in future solar cell technologies	MITI, PEMANDU, EPU	1. Increased international trade in solar energy sector 2. Sustained demands solar product and services 3. 80% of local electricity demand is met by renewable resources, predominantly solar
Infrastructure	Large-scale technology deployments in everyday physical infrastructures	Property developers, technology owners, local authorities	Solar energy towns and cities.
Value chain and market development	Intensification of Malaysian R&D branding and commercialisation	MITI, private investors, angel investors, start up companies	Malaysian-owned-and-operated operations along the entire technology value, providing services to the world market

Resource

Resource/Year	2020	2030	2040	2050
Supply Chain-Local content / Raw material	10%	20%	30%	40%
Investment RM1000M	FIT-reduced payback period	Increased Funding for R&D	Subsidized installation cost	RPS - Generator to generate minimum % from PV source
Staff/Skills	Expertise: Scientist, Engineers, Chemist, Physicist, Government Skills: courses at UG and PG level, University-Industry collaboration R&D			

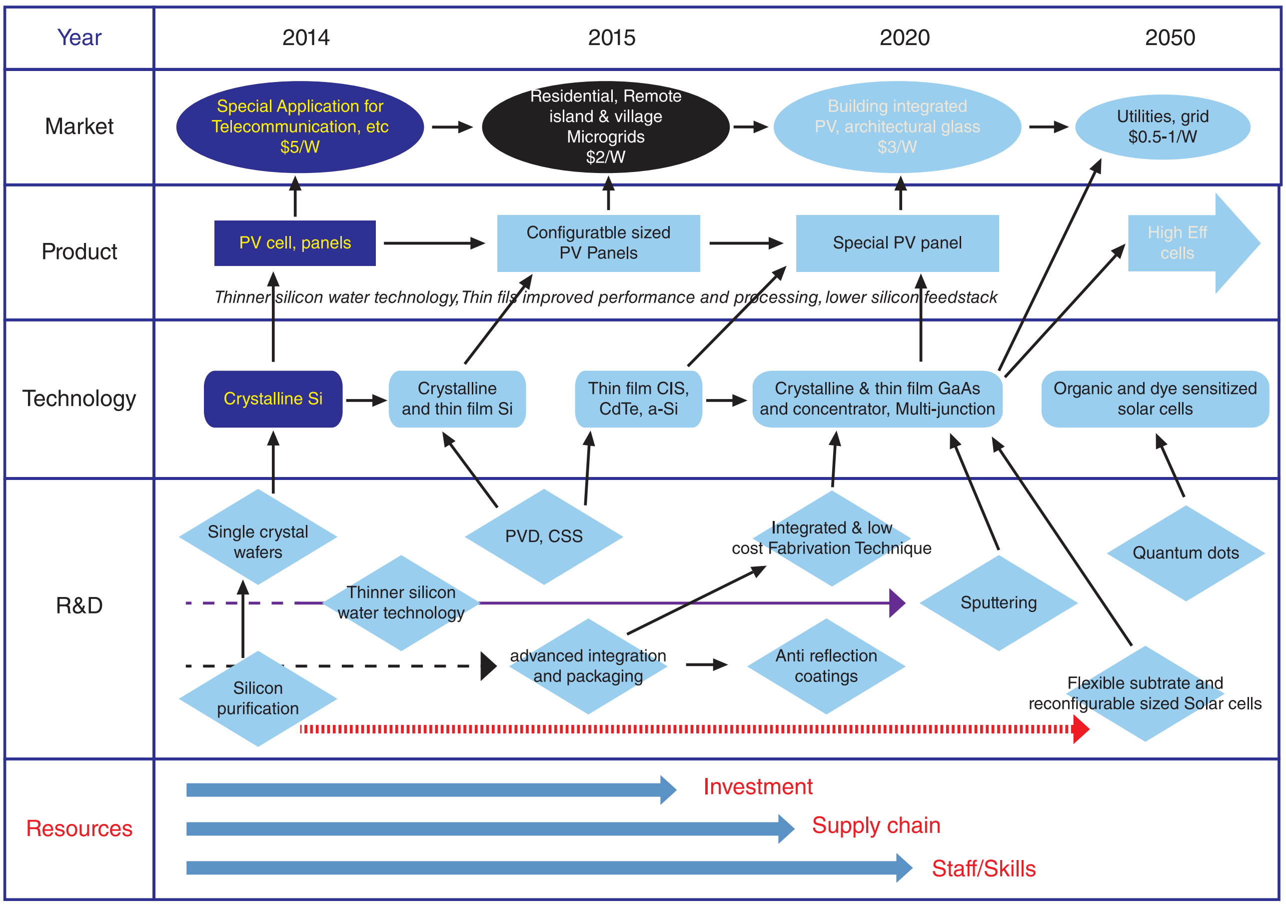


Figure 9.4 Roadmap and resources for Malaysian Solar PV Industry (2014 – 2050)

9.5 ACTION PLAN FOR MALAYSIA'S SOLAR THERMAL INDUSTRY

Currently, solar thermal cumulative capacity in Malaysia is estimated to be 0.5 GWth. The target is to increase it by 7 GWth by the year 2050, by applications of solar water heating in residential, public, commercial, and industrial sectors. These can be achieved by effective policy framework, attractive financial mechanism, improvement of local manufacturing capabilities, and increased funding for R&D.

Table 9.4 and **Table 9.5** illustrate the R&D action plan, as well as the target market for liquid- and air-based solar thermal systems, respectively. The near-term target applications include large-scale solar hot water heating for hospitals and hotels. The medium-term targeted system deployments are for residential and non-residential water-heating systems, and industrial process heat such as detoxification, chemical, distilling, textile and food industries. Over the long-term, the targeted applications include residential and non-residential water-heating system, solar-cooling system e.g. liquid desiccant air conditioner, and industrial process heat**.** R&D operations focusing on efficiency improvement and cost-reduction of solar thermal collectors are top priorities. In addition, highly efficient thermal storage systems must also be developed. These are summarised in **Figure 9.62**, showing the roadmap for both types of solar thermal systems. **Table 9.22** and **Figure 9.63** show the R&D activities and the roadmap for PVT technologies, respectively.

Table 9.4 R&D Action Plan for Liquid-Based Solar Water Heater

Current	Shot Term 2015-202	Mid Term 2020-2040	Long Term 2040-2050	Scenario
Liquid based solar water heater	Residential and non residential hot water system e.g. hospitals and hotels, low temperature industrialised process heat, textile industry	Residential and non residential hot water system e.g. hospitals hotels and industrial process heat (detoxification, chemical distilling, textile and food industries)	Residential and non residential hot water system and solar cooling system e.g. liquid desiccant air conditioner and industrial process heat (detoxification, chemical distilling, textile and food industries)	Efficiency: Evacuated tube - < 50% target <60% Solar thermal collector (Liquid based) - 45% target 55%

Table 9.5 R&D Action Plan for Air-Based Solar Water Heater

Current	Shot Term 2015-202	Mid Term 2020-2040	Long Term 2040-2050	Scenario
Air based solar heater 1. Solar thermal collector (Air type)	Non residential hot air system e.g. agriculture, drying and food industries	Non residential hot air system e.g. heat pump for agriculture, drying and food industries	Non residential hot air system e.g. large scale heat pump for agriculture, drying and food industries	Efficiency: Solar thermal collector (Air based) - 30% target 40%

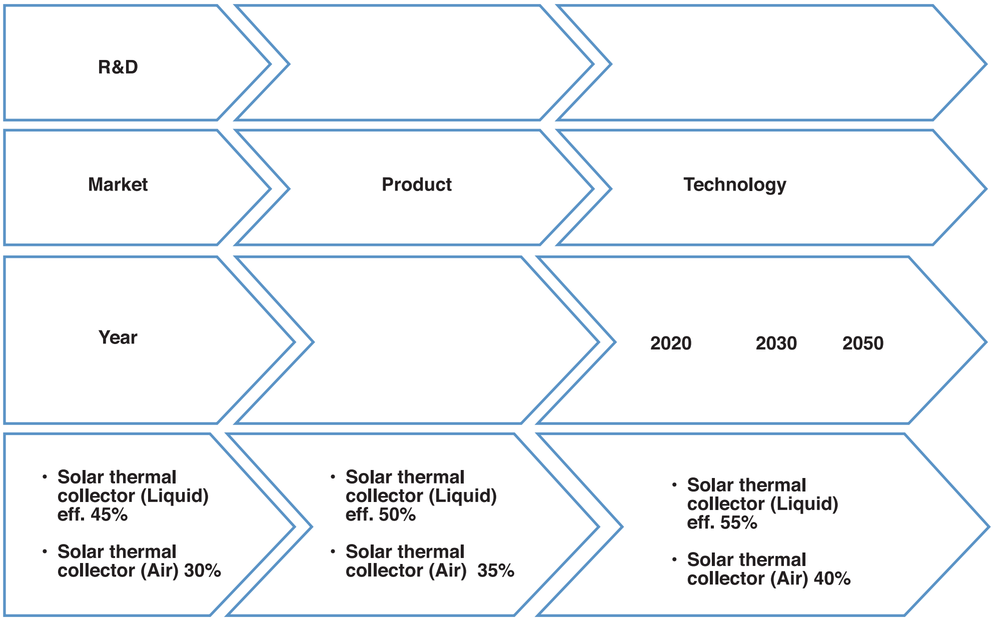


Figure 9.5 Roadmap for Malaysian Solar Thermal Heating Industry

Table 9.6 R&D Action Plan for PVT Systems

• New coating material for collector - Titanium Nitrite Oxide (TiNOX) • New glazing material e.g. Polycarbonate, nanofluids	Liquid based solar heater 1GWth Air based solar heater 0.3 GWth	Liquid based solar heater 5 GWth Air based solar heater 1 GWth	• Solar collector made of metal absorber e.g. copper, aluminum and stainless steel. • Insulator material – thermoplastic, nanofluids • Advance coating material – Nano coated surface. • New concentrating material – Fresnel lens + extreme concentrated photovoltaic
• Improving collector system design and performance • Improve contact between the tube and solar collector. • Investigation on insulator. • Advanced simulation tools for system modeling at difference scale. Liquid based solar heater 0.4 GWth Air based solar heater 0.1 GWth	• Laser, plasma and ultrasonic welding for collector. • Nano coated surfaces for reduce friction losses of fluid flow. • Development of Photovoltaic Thermal Solar Collector • Nanofluids	• Industrial collector molding. • Integration	**Short Term 2015 - 2020**

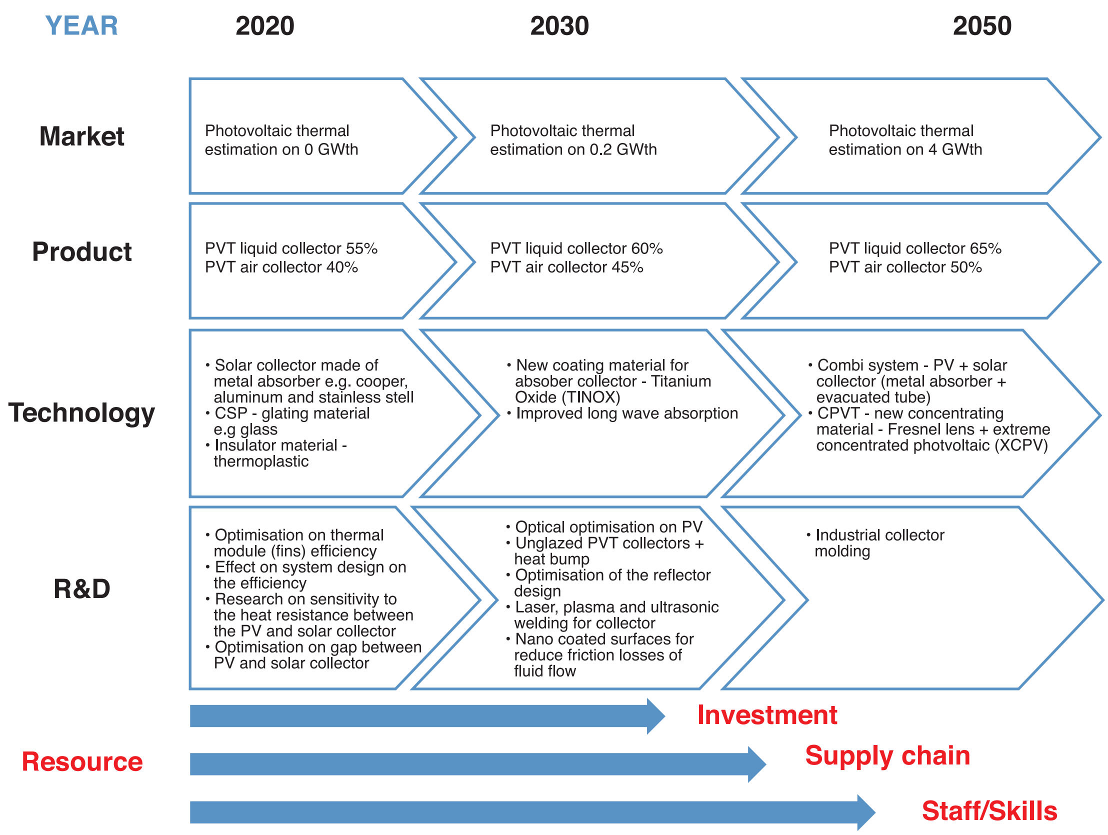


Figure 9.6 Roadmap for Malaysian PVT Systems

9.6 CONCLUDING REMARKS

Malaysia's competitive edge in the solar energy industry lies in its all-year round sunlight, abundance of silicon, and well-established infrastructure to support the entire solar PV supply chain. Unfortunately, multinational companies thriving on cheap local labour and natural resources currently dominate the solar cell manufacturing industry in Malaysia; with almost all of their finished products are exported back to their home countries. Consistent efficiency and reliability improvements, as well as cost reduction, are critical contributing factors to the global expansion of Malaysian PV industry. Furthermore, vertical-integrated manufacturing of silicon solar cells, covering both frontend and backend processes of making solar panels must be established. The crystalline silicon PV technology will continue play a leading role in solar PV industry. Silicon is also the current dominant component of integrated circuit (IC) electronics; hence, advances in IC fabrication technologies will be also accessible to the PV industry. In addition, R&D in solar thermal technologies, with the aim of reducing the cost and also improvements in the overall efficiency of the system for solar-drying, solar hot water heating systems, solar detoxification, solar desalination, and solar cooling must be carried out by institutions of higher learning and research institutes.

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