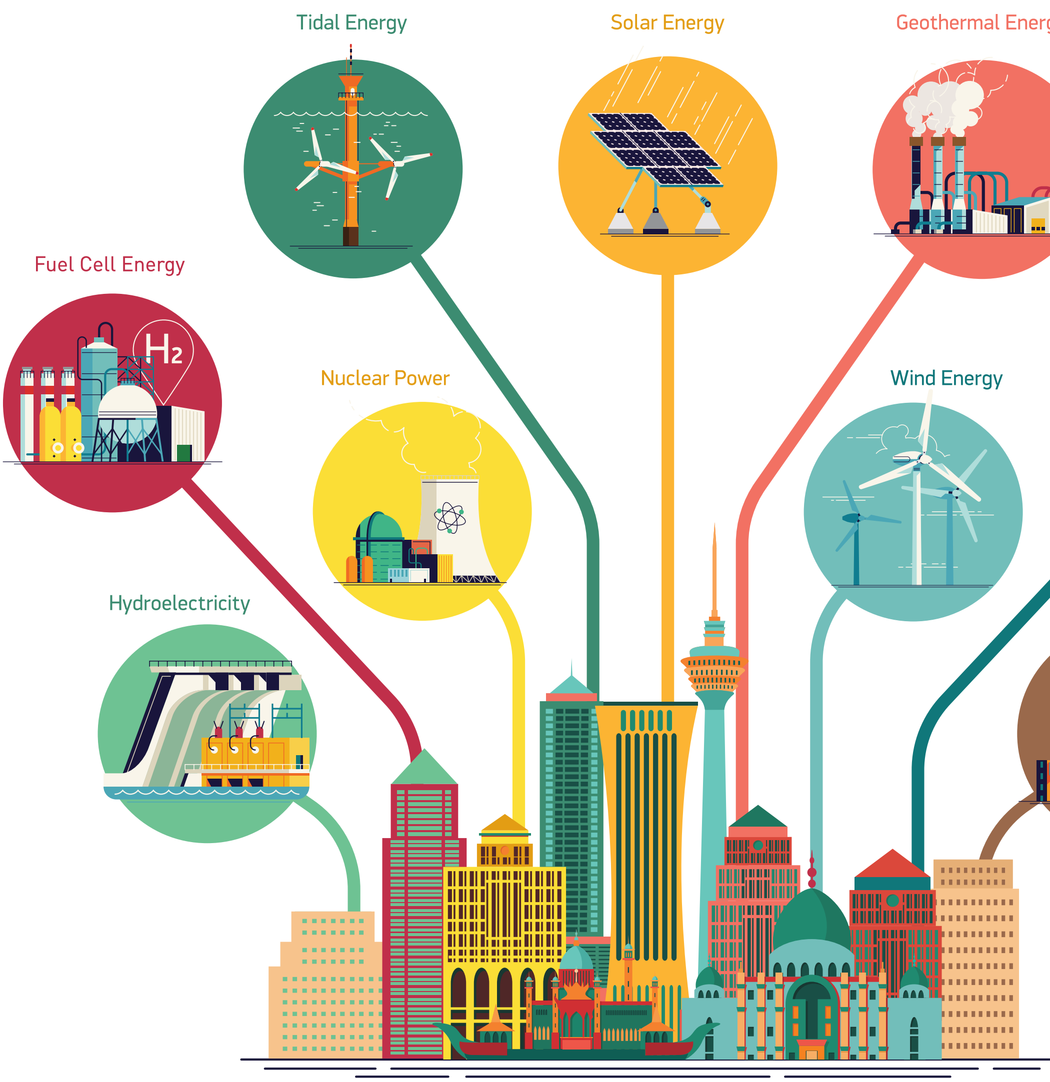
CARBON FREE ENERGY:
ROADMAP FOR MALAYSIA



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ROADMAP FOR MALAYSIA

AKADEMI SAINS MALAYSIA

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Contents

Foreword

In carrying out its mandate as the 'Thought Leader' in science, technology and innovation (STI), the Academy of Sciences Malaysia (ASM) has always endeavoured to address the nation's highest concerns. On the energy front, the focus of ASM's strategic studies has been on greening energy through technology. Malaysia has responded to anticipated energy security crisis and climate change risks by diversifying fuel-resources to include renewable and alternative energy as well as developing green technologies for the future. In consonance with this, ASM completed three energy related advisory reports this year namely Carbon Free Energy Roadmap, Energy Efficiency and Energy Usage in Transportation, and Blueprint for Fuel Cell Industries in Malaysia.

The global energy landscape is rapidly changing to respond to growing demand and the need to minimise environmental impact. Today, we are not totally reliant on fossil fuels for energy. Energy sources are more diversified ranging from the deep below the ocean floor, the sun, wind, biomass, beds of shale rock as well as nuclear fission. However, sources of energy which are relevant to Malaysia need to be effectively harnessed through science, technology and innovation.

Malaysia pledged a voluntary reduction of up to 40% in terms of emissions intensity of gross domestic product (GDP) by the year 2020 compared to 2005 levels at the Conference of Parties (COP15) to the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in 2009. To ensure the achievement of this target, Malaysia has embarked on implementing several national policies, legislation and strategies such as the National Green Technology Policy (2009), National Renewable Energy Policy and Action Plan (2010), New Energy Policy (2010), Renewable Energy Act (2011) and National Biomass Strategy 2020 (2011). The adoption of renewable energy and promotion of energy efficiency initiatives are important to meet Malaysia's energy needs in the long run.

In playing our part to contribute to this effort, ASM through its Task Force on Carbon Free Energy embarked on this study and developed the roadmap for Malaysia to achieve net zero carbon emission by 2050. The task force has engaged various stakeholders and experts in the energy arena during the course of this study. I believe this report is timely as we usher a new era of energy possibilities through cutting edge scientific interventions and technologies.

I wish to congratulate the ASM Task Force on Carbon Free Energy chaired by Professor Dato' Dr Kamaruzzaman Sopian FASc for producing this advisory report. This Report would not have been possible without the strong support, cooperation as well as relevant constructive input from various parties including Government ministries and agencies, the scientific community, industry practitioners as well as the corporate sector.

I hope this advisory report would provide valuable insights towards ensuring a secure and sustainable energy future for Malaysia.

Tan Sri Dr Ahmad Tajuddin Ali FASc.
President of the Academy of Sciences Malaysia

Preface

Malaysia's commitment at the United Nations Climate Change Conference 2009 (COP 15) to reduce up to 40% of its emission intensity of GDP by the year 2020 compared to the 2005 levels has resulted in several national level renewable power capacity targets. These include the achievement of 985 MW of installed renewable power capacity by 2015, contributing 6% of generation, rising to 11% in 2020, 17% in 2030 and 73% in 2050. Nonetheless, as of 31 December 2014, only 243.4 MW has been connected to the grid and this represents only about 1% of the total installed capacity in Peninsular Malaysia and Sabah. Meeting the set target is a big challenge. Hence, it is necessary to develop an achievable roadmap considering the adoption of appropriate policies and strategies as well as enhancement of a sustainable market for relevant technologies.

Though there were earlier roadmaps developed by various agencies for renewable energy technologies, none of these roadmaps were designed based on carbon emission from the energy sector. Thus, the ASM Task Force on Carbon Free Energy embarked on developing a roadmap with a set target to achieve a carbon free energy future by 2050. The energy targets by this task force were set through scenario analysis in which the task force identified the desirable future and conducted "back-casting" instead of the normal "forecasting". Thus, development paths between the future and the present were created in terms of strategies and concrete action plans, describing a continuous process of change towards realising the desirable future. Nevertheless, the scope of this roadmap focuses only on the electricity sector with a projection period of 2015 to 2050.

"Carbon free" in this roadmap has been defined as "net zero carbon emissions" where the total carbon dioxide emission avoidance from the carbon free energy resources will off-set the emissions from the fossil fuels combustion by 2050; whereas the "Carbon free energy resources" refer to resources that have no carbon emission or with net zero emissions of carbon. Therefore, the energy resources considered in this roadmap are bioenergy, geothermal, hydropower, nuclear energy, ocean thermal energy conversion (OTEC), solar photovoltaic (PV), wave and tidal current as well as wind energy. Moreover, hydrogen generation from renewable energy as an energy carrier has been proposed by this task force and consequently fuel cell technology has been included in this present roadmap.

The task force has reviewed the potential of the carbon free energy resources and their challenges, followed by the development of a roadmap, back-casting of the scenarios from 2050 to the present. Recommendations and action plans were also deliberated through brainstorming sessions with the stakeholders.

In order to achieve these ambitious energy targets and goals, a diversified energy mix is crucial. This roadmap excels in exploring all kinds of indigenous carbon free energy resources including the potential of fuel cell technology, compared to other existing roadmaps that only considered a few types of renewable energy. Hence, this report provides insights and a quantitative framework for policymakers to understand the supply and demand of the future energy trends. This would facilitate the formulation of appropriate policies and targets to address energy related issues and challenges.

Professor Dato' Dr Kamaruzzaman Sopian FASc,
Chairman of ASM Task Force on Carbon Free Energy

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The task force would like to thank those who participated and contributed towards the shaping of the Carbon-Free Energy vision.

Abbreviations

ASEAN	Association of Southeast Asian Nations
ASM	Academy of Sciences Malaysia
CAAGR	Compounded Average Annual Growth Rate
capex	Capital expenditures
CO_2	Carbon Dioxide
EFB	Empty fruit bunches
EPP	Entry Point Project
EPU	Economic Planning Unit
ETP	Economic Transformation Programme
FMM	Federation of Malaysian Manufacturers
GDP	Gross Domestic Product
GNI	Gross national income
GWh	Gigawatt-hour
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
INTAN	Institut Tadbiran Awam Negara
JLM	Jabatan Laut Malaysia
JMGM	Jabatan Mineral dan Geosains Malaysia
JKR	Jabatan Kerja Raya
JPN	Jabatan Pendaftaran Negara
JPS	Jabatan Perairan and Saliran
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
KeTTHA	Kementerian Tenaga, Teknologi Hijau dan Air/ Ministry of Energy, Green Technology and Water
KKLW	Kementerian Kemajuan Luar Bandar dan Wilayah Malaysia/ Ministry of Rural & Regional Development
LNG	Liquefied natural gas
MDV	Malaysia Debt Ventures Berhad
MGTC	Malaysian Green Technology Corporation

MIDA	Malaysian Investment Development Authority
METMalaysia	Malaysian Meteorological Department
MF	Mesocarp fiber
MITI	Ministry of International Trade and Industry
MNPC	Malaysia Nuclear Power Corporation
MOA	Ministry of Agriculture
MOE	Ministry of Education
MOF	Ministry of Finance
MOHA	Ministry of Home Affairs
MOHE	Ministry of Higher Education
MOSTI	Ministry of Science, Technology and Innovation
MOTAC	Ministry of Tourism and Culture Malaysia
MSW	Municipal solid waste
MW	Megawatt
NAHRIM	National Hydraulic Research Institute of Malaysia
NanoMalaysia	NanoMalaysia Berhad
NBS	National Biomass Strategy
NEB	National Energy Balance
NGO	Non-Government Organisation
NKEAs	National Key Economic Areas
NRE	Ministry of Natural Reseaorces and Environment
OTEC	Ocean thermal energy conversion
PKS	Palm-kernel shells
POME	Palm oil mill effluent
PV	Photovoltaic
RE	Renewable energy
SEB	Sarawak Energy Berhad
SEDA	Sustainable Energy Development Authority
SESB	Sabah Electricity Sdn Bhd
SIRIM	SIRIM Berhad, formerly known as the Standards and Industrial Research Institute of Malaysia
SPV	Special Purpose Vehicle
ST	Suruhanjaya Tenaga
STIPAC	Science Technology Innovation Policy Advisory Committee
TATIUC	TATI University College
TCT	Tidal current turbine

TES	Total energy supply
TGE	Tawau Geothermal Energy
TNB	Tenaga national Berhad
UMS	Universiti Malaysia Sabah
UKM	Universiti Kebangsaan Malaysia
UM	Universiti Malaya
UNIMAS	Universiti Malaysia Sarawak
UNITEN	Universiti Tenaga Malaysia
UPM	Universiti Putra Malaysia
UTM	Universiti Teknologi Malaysia
UTP	Universiti Teknologi PETRONAS

Executive Summary

The main deliverable of the Carbon-Free Energy Task Force is the Carbon-Free Energy Roadmap for Malaysia (2015 – 2050).

The roadmap aims to assess the prospects of energy mixes and actions that need to be undertaken to achieve a carbon-free energy future for Malaysia. Furthermore, the roadmap also provides policymakers a quantitative framework to understand the supply and demand of the future energy trends and hence to formulate appropriate policies and targets to address energy related issues and challenges.

The scope of the roadmap focuses only on the electricity sector for the projected period of 2015 to 2050. Carbon-free energy in this report refers to energy sources that have no carbon emission or with net zero emissions of carbon. These energy resources are bioenergy, geothermal, hydropower, nuclear energy, ocean thermal energy conversion (OTEC), solar photovoltaic (PV), wave and tidal current, and wind energy. Moreover, hydrogen generation from renewable energy as an energy carrier was also proposed by this task force, and thus fuel cell was included as an additional energy conversion system during the later stage of the roadmap development process.

This roadmap has been developed through a series of meetings to gather inputs and discussions on the technological and deployment issues among the task force committee. In addition, the task force conducted a Carbon-Free Energy Roadmap Workshop in Malacca, from 20 to 22 January 2015. Stakeholders from universities, power sectors, R&D institutions, finance community, industries and government institutions were invited to the workshop for brainstorming sessions to discuss the targets and action plans for the carbon-free energy vision.

After the workshop, the scope and targets were further reviewed and revised through several meetings and email communications. The task force arrived at two different scenarios for the carbon-free energy roadmap. Scenario-1 aims to achieve carbon-free energy mix in electricity generation by 2050; and Scenario-2 aims to achieve net zero carbon emissions in electricity generation by 2050. Highlights of the findings are summarised as follows:

Scenario-1: Carbon Free Energy Mix in Electricity Generation

In this scenario, carbon free energy sources have been introduced, **and by 2050, *fossil fuels will be completely phased out*** and replaced by eight types of alternative resources in energy mix:

1) Among these resources, **OTEC** with an estimated capacity factor of 0.9 can be the main supplier of energy. Hence, this comprises about 41% of the electricity generation mainly for the production of hydrogen.
2) **Wind energy**, would be the second major resource for electricity supply. This wind energy is generated from on and offshore facilities.
3) **Combined wave and tidal current energy** will be the next important resource for electricity generation.
4) **Solar PV**, whilst its technology and market have been well developed, the low capacity factor remains a constraint due to the low availability of resources (4 hours during daytime only). Nonetheless, the peak performance operational time of solar PV – midday - happens to be also the peak demand period of the day. This gives an advantage to solar PV in supplying for peaking loads.
5) Presently, the main sources for **bioenergy** in Malaysia are the biomass from the oil palm industry. However, the wastes of the oil palm can be turned into value-added products such as fertilisers and animal feedstock that can generate more income. It is not extensively used as an energy resource for electricity generation. Hence, it is expected that in the future, the main sources for bioenergy in electricity generation would come from municipal solid waste and biogas despite the abundance of oil palm wastes.
6) The first **nuclear** power station has been planned for 2021. In this report, it is assumed that a total of 2 GW nuclear power plants will be in place by 2025. This energy resource can help in supplying non-carbon electricity for the medium term action plan due to the fact that other alternative resources might take a longer time to be developed.
7) **Hydropower** plants in Malaysia are mainly commissioned for large-scale electricity generation. The operational capacity needs to be controlled in relation to its environmental impact. Hydropower has been used as peaking power plants and for reserve margin. These strategies will be continued in future energy mixes.
8) **Geothermal** is relatively a new technology in Malaysia. Its technology will take a longer time to develop due the lack of expertise and experience. In addition, suitable sites for geothermal are limited in Sabah. These contributing factors mean geothermal will have the smallest share in electricity generation.

The projections show that between 2035 and 2040, the present proposed energy mix will be able to achieve a net zero CO_2 emission in the electricity sector. Furthermore, in 2050, the total avoidance is about 217 Gtonnes of CO_2. This amount is equivalent to approximately the amount of emission avoided from 106petagrams of coal burned.

Scenario-2: Net Zero Carbon Emissions

In this scenario, the ***total carbon dioxide emission avoidance from carbon free energy sources will offset the emissions from fossil fuel combustion by 2050***. Fossil fuels together with nine carbon free energy resources will contribute to in future energy mix as follows:

1) **Fossil fuels** will play an important role in power generation, however, its share of electricity generation in 2050 (97%) will be reduced by more than half (42%) compared to 2012.
2) Among the carbon-free energy resources, **OTEC** will be the main supplier, accounting to about 17% of electricity generation by 2050. Furthermore, 50% of its total installed capacity will be used for hydrogen generation by 2050, making it the main energy source for hydrogen generation.
3) **Fuel cell** will be the next important energy conversion system after OTEC. However, full cell will rely on other carbon-free energy sources that contribute to hydrogen production. The share of fuel cell in electricity generation (2020-2050) can only be achieved if the energy supply for hydrogen production is sufficient.
4) The capacity factor of **bioenergy** is higher compared to wind energy and solar PV. Moreover, electricity generation from the bioenergy is higher compared to wind and PV, although it has a smaller amount of installed capacity. In this scenario, it is assumed that about 90% of municipal solid wastes will be treated by incineration. Furthermore, municipal solid wastes will contribute significantly in the electricity generation mix.
5) **Wind energy** will be the fifth major energy source for electricity generation by 2050.
6) **Solar PV** shares about the same amount of installed capacity as wind energy. However, electricity generation from the PV is less than wind because of its lower capacity factor.
7) **Nuclear** energy will supply non-carbon electricity in the medium-term action plan. Nuclear energy technology is relatively more mature than other carbon-free energy resources in terms of big-scale commercial power plants. Hence, nuclear energy is able to ease the reduction of fossil fuel consumption when other carbon-free energy technologies are still in their developing stages.
8) The combination of **wave energy and tidal current energy** will be the next important source that can contribute to electricity generation.
9) **Hydropower** plants in Malaysia are mainly large scale. They are used as peaking plants and reserve margin. However, the operational capacity needs to be controlled to safeguard the environment.
10) **Geothermal** is relatively a new technology in Malaysia. Due to lack of expertise and experience, it will take a longer time to develop the technology. In addition, suitable sites for geothermal are limited. This results in geothermal resources as having the smallest share in electricity generation.

The projections show that by 2050, the present proposed energy mix would be able to offset emissions from fossil fuel combustion and finally achieve a net zero CO_2 emission in the electricity sector. In 2050, the total avoidance is about 92 billion tonnes of CO_2. This amount is equivalent to approximately emission avoided from 44 petagrams of coal burned.

Conclusions and Key Messages to Decision Makers

Based on the findings, the task force would like to propose that Scenario-2 is adopted as the Carbon-Free Energy Roadmap for Malaysia. In this scenario, the "Carbon-Free Energy" is referred to as "the total carbon dioxide emission avoidance from carbon-free energy sources that will offset emissions from fossil fuel combustion by 2050 in the energy mix".

Key measures that the team would like to highlight to the decision makers are as follows:

1. **Increase the share of renewable energy (RE) in the energy mix by setting long-term targets for RE deployment, consistent with national energy strategies and national contributions to global climate change mitigation efforts.**
2. **Explore the potential of RE resources of wind, OTEC, wave and tidal current, and geothermal.**
3. **Explore fuel cell technologies, including the potential of large-scale applications (power plant) for hydrogen economy in the future.**
4. **Strengthen research and development, knowledge and technology transfer through international collaboration, demonstration and deployment in local context.**
6. **Enhance personnel capacity in RE through training courses, university and school curriculums.**
7. **Advanced planning of new RE plants and thus address issues related to land use and sea use planning.**
8. **Develop a finance mechanism that would attract and aide renewable energy project developers.**
9. **Integrate energy policy with national mitigation and adaptation plans to address climate change issues.**
10. **Strengthen the institutional framework in planning, implementing, monitoring and evaluating the policies and projects related to energy and climate change mitigation.**

Chapter 1

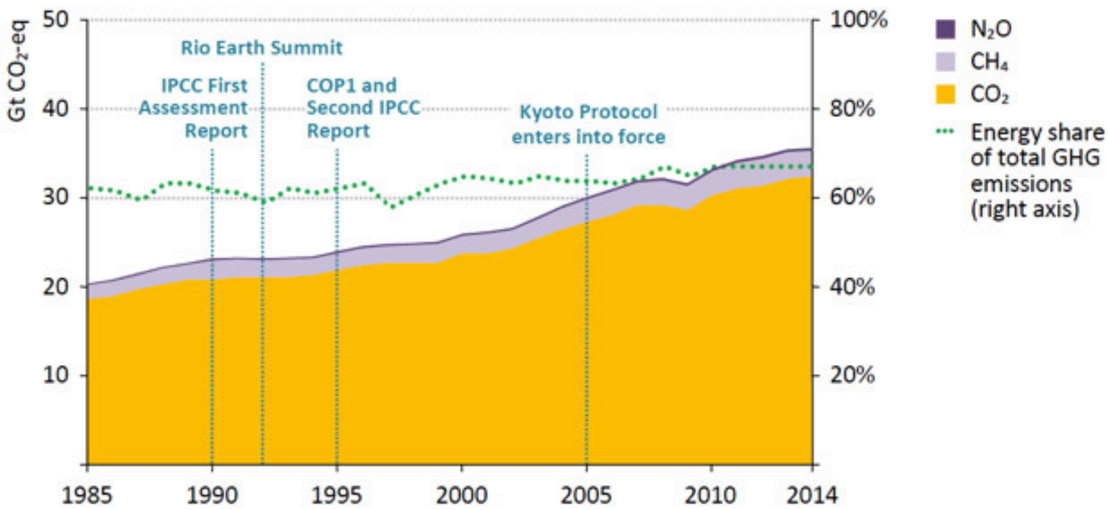
Background & Introduction

1.1 Background

Energy Sector and Climate Change

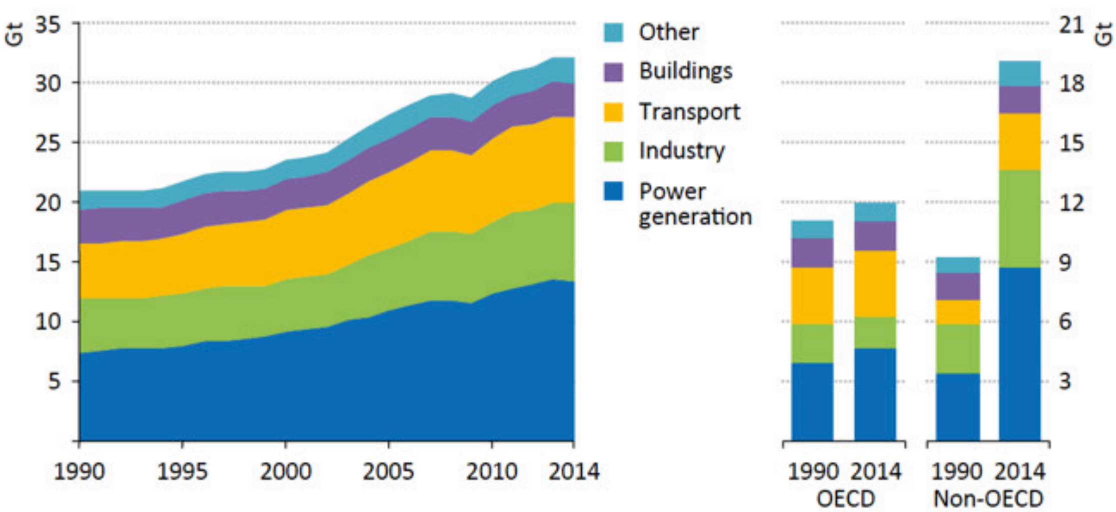
The Kyoto Protocol legally binds developed countries to emission reduction targets. The Protocol's first commitment period started in 2008 and ended in 2012. At the Conference of the Parties (COP) 16 in Cancun in December 2010, 196 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed a long-term global goal of limiting the increase in global average temperature below 2°C relative to pre-industrial levels; whereby the concentration of greenhouse gases stabilises after 2100 at around 450ppm – "450 Scenario". The second commitment period began on 1 January 2013 and will end in 2020. Hence, the Parties will meet at the COP 21 to sign a new climate change agreement (Paris Declaration) pledging support for an international climate deal in December 2015. Prior to the COP 21, countries accounting for 34% of global energy-related emissions had submitted their Intended Nationally Determined Contributions (INDCs) by 14 May 2015. The IEA has undertaken a first assessment of newly declared government intentions, with the results presented through an "INDC Scenario".

According to the IEA report (2015), as of 2014, more than 60% of the global anthropogenic CO_2 emissions are from the energy sector (Figure 1.1-1), and these emissions by sector are as shown in Figure 1.1-2. Electricity generation remains as the dominant emitter since 1990, even though the share of renewables in power generation has been increasing gradually since 2000 (Figure 1.1-3).



Notes: CO_2 = carbon dioxide, CH_4 = methane, N_2O = nitrous oxide. CH_4 has a global warming potential of 28 to 30 times that of CO_2, while the global warming potential of N_2O is 265 higher than that of CO_2.

Figure 1.1-1 Global anthropogenic energy-related greenhouse-gas emissions by type
(Source: IEA, 2015)



Notes: "Other includes agriculture non-energy use (except petrochemical feedstock), oil and gas extraction and energy transformation. International bunkers are included in the transport sector at the global level but excluded from the regional data.

Figure 1.1-2 Global energy-related CO_2 emissions by sector

(Source: IEA, 2015)

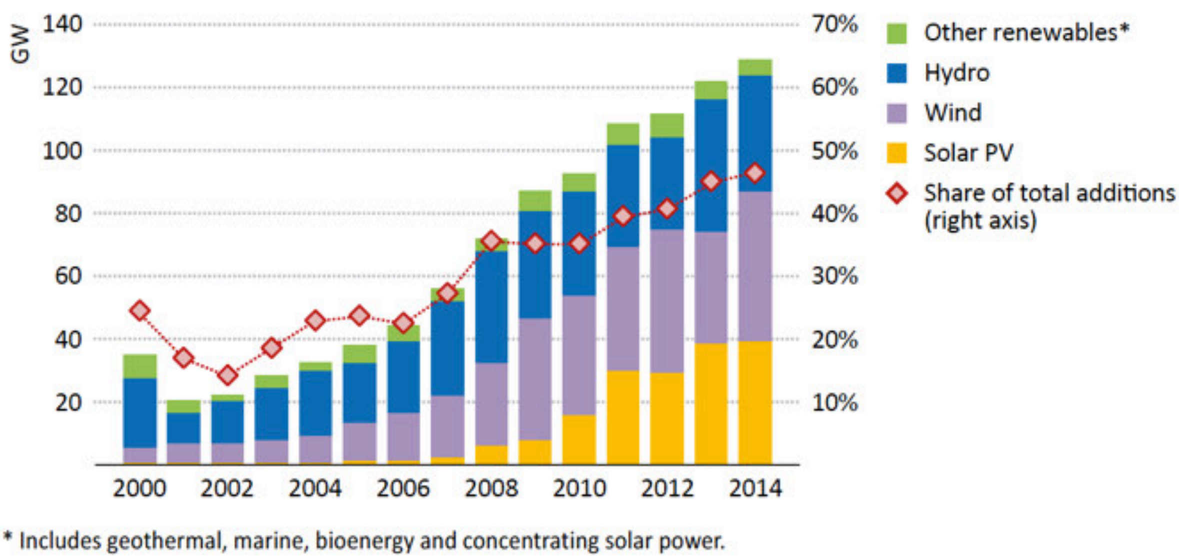
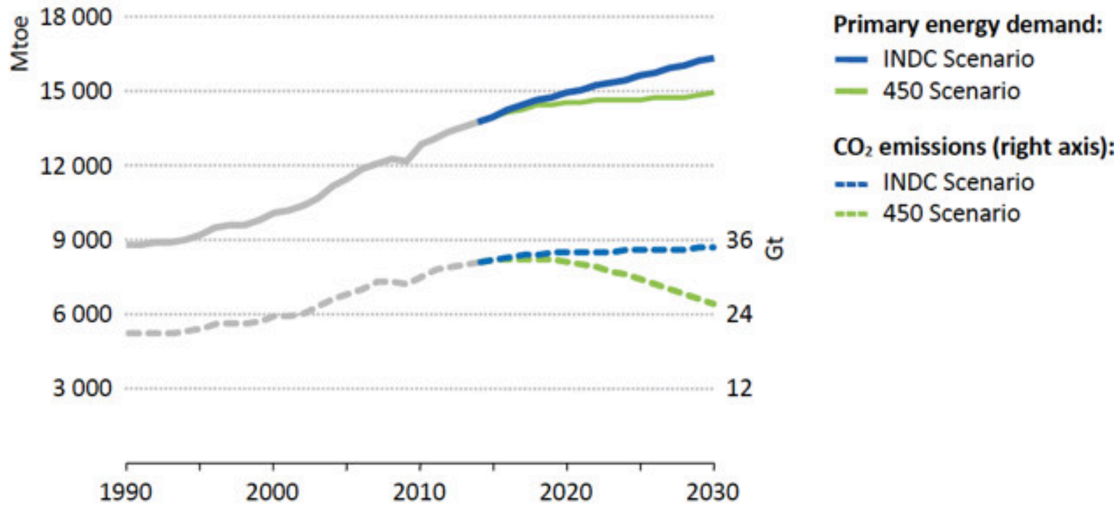


Figure 1.1-3 Global renewable energy in power generation by type

(Source: IEA, 2015)

With regard to future projections, the global primary energy demand, the CO_2 emissions of INDC Scenario and the 450 Scenario are compared in Figure 1.1-4. It can be seen that there are gaps in realising the 450 Scenario. Neither the scale nor the composition of energy sector investment in the INDC Scenario is suited to move the world onto a 2°C path. Figure 1.1-5 shows the global energy-related CO_2 emissions in the INDC Scenario and remaining carbon budget for a >50% chance of keeping to 2°C. The study found that this carbon budget would be completely consumed by around 2040. Without stronger actions, this may result in a global temperature increase of around 2.6°C in 2100 and 3.5°C after 2200.



Note: Mtoe = million tonnes of oil equivalent; Gt = gigatonnes.

Figure 1.1-4 Global primary energy demand and related CO_2 emissions for Scenarios of INDC and 450 (Source: IEA, 2015)

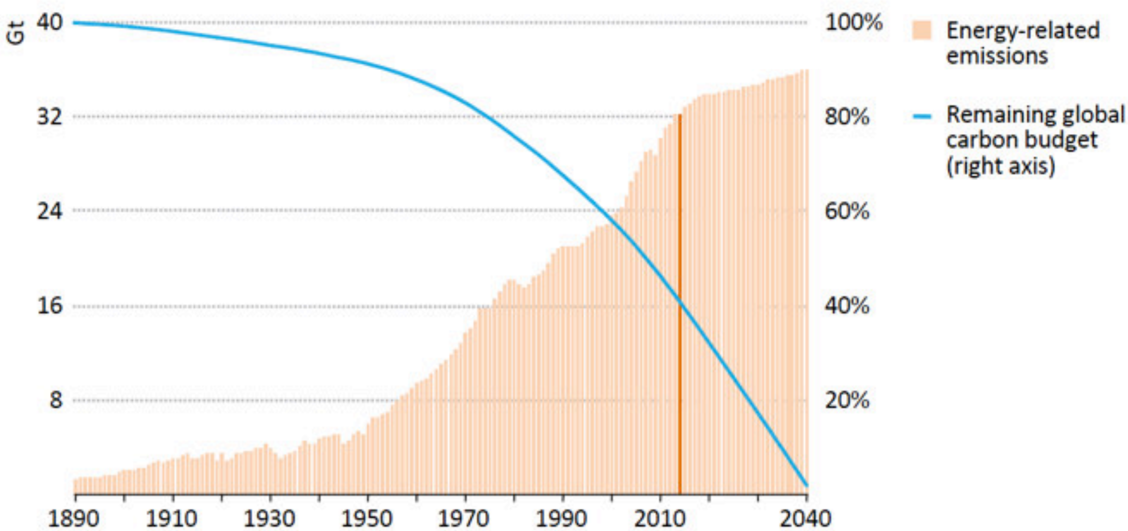


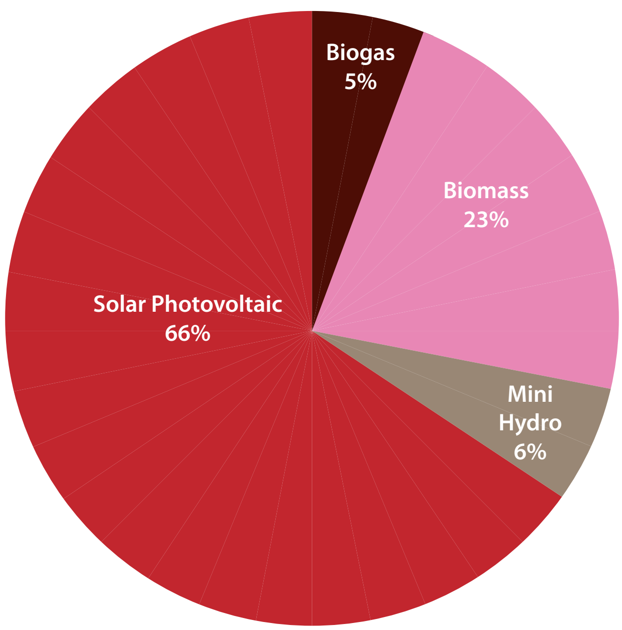
Figure 1.1-5 Global energy-related CO_2 emissions in the INDC Scenario and remaining carbon budget for a >50% chance of keeping to 2 °C

(Source: IEA, 2015)

Energy Mix in Malaysia

SEDA has targeted 415.5 MW of RE out of the total installed capacity by 2014. However, as of 31 December 2014, only 243.4 MW was connected to the grid, which is only about 1% of the total installed capacity in Peninsular Malaysia and Sabah (Figure 1.1-6). In terms of CO_2 emission, Malaysia has set a voluntary target of reducing GHGs emission by 40% carbon intensity to the gross domestic product (GDP) by 2020 as compared to 2005 baseline.

As of 2013, Malaysia has reduced GHGs emission by 432,000 tCO_2eq and this accounted for a reduction of carbon intensity of 33%. For the way forward, RE capacity is expected to reach 2,080 MW by 2020, contributing to 7.8% of total installed capacity in Peninsular Malaysia and Sabah (EPU 2015).



Total installed capacity in 2014: 243.4 MW

Figure 1.1-6 Share of grid-connected renewable energy in power generation mix in 2014 (Source: EPU, 2015)

1.2 Introduction to Carbon Free Energy Task Force

Currently, the RE potentials in Malaysia is focused only on solar, biogas, biomass and mini-hydro. RE in the power generation mix can be higher than the existing targets and achievements if other types of RE can be explored. The present task force's challenge is to target carbon-free energy by 2050. Thus, the availabilities of all types of non-carbon energy sources were taken into account in setting the targets to develop a roadmap in achieving a carbon-free energy future.

The objectives of the Carbon Free Energy Task Force are:

i) To identify the major stakeholders involved in carbon-free energy, research and development;
ii) To identify the issues faced in implementing carbon-free energy; and
iii) To develop a blueprint and roadmap for a carbon-free energy programme in Malaysia including proper funding, public engagement and awareness programmes.

Therefore, the main deliverable of the task force is the Carbon Free Energy Roadmap for Malaysia, and thus, forms the main contents of this report.

Purpose, Scope and Development Process of Carbon Free Energy Roadmap

The roadmap aims to assess the prospects of energy mix and actions that need to be undertaken to achieve a carbon-free energy future for Malaysia. Furthermore, the roadmap also provides policymakers a quantitative framework to understand the supply and demand of the future energy trends, and hence, to formulate appropriate policies and targets to address energy related issues and challenges.

The scope of the roadmap focuses only on the electricity sector for the projected period of 2015 to 2050. Carbon free energy in this report refers to energy sources that have no carbon emission or with net zero emissions of carbon. These energy resources are bioenergy, geothermal, hydropower, nuclear energy, ocean thermal energy conversion (OTEC), solar photovoltaic (PV), wave and tidal current, and wind energy. Moreover, hydrogen generation from renewable energy as an energy carrier is also proposed in this task force, and thus, fuel cell is included as an additional energy conversion system at the later stage of the roadmap development process.

This roadmap was developed through series of meetings to gather inputs and numerous discussion on the technological and deployment issues among the task force committee. In addition, the task force committee conducted a Carbon Free Energy Roadmap Workshop in Malacca, from 20 to 22 January 2015. Stakeholders from universities, power sectors, R&D institutions, finance community, industries and government institutions were invited to the workshop for brainstorming sessions to discuss the targets and action plans of a carbon free energy vision.

After the workshop, the scope and targets were further reviewed and revised through several meetings and email communications. Details of the development process are further discussed in Chapter 3.

Structure of this Roadmap

i) Chapter 2 discusses the current status of the carbon free energy technologies, applications and initiatives in Malaysia;

ii) Chapter 3 explains the roadmap development process and discusses the projections of energy supply, as well as the vision with deployment targets for carbon free energy future by 2050;

iii) Chapter 4 concludes the roadmap with proposed actions complete with time frames to overcome barriers and challenges, as well as the necessary R&D activities; and

iv) Chapter 5 summarises the roadmap with key messages to the decision makers.

Chapter 2

The Current Status of Carbon Free Energy Technologies

2.1 Bioenergy

Bioenergy resources are renewable organic matters, which include forest and mill residues, wood wastes, agricultural crops and wastes, animal wastes and municipal solid wastes (MSW). Agricultural crops are such as sugarcane, cassava and corn; agricultural residues are such as rice straw, cassava rhizome, corncobs, oil palm fronds; wood & wood residues are such as fast-growing trees and wood waste from wood mill; and waste stream resources are such as rice husks from rice mills, molasses and bagasse from sugar refineries, residues from palm oil mills and MSW.

2.1.1 State of the Art

Malaysia has been utilising biomass to produce wood products, animal feed, energy, as well as using it directly as fertilisers. Furthermore, bioenergy plants are being built to take advantage of the Feed-in-Tariff. In fact, the first pellet plant has been set up, from which pellets are produced for domestic use and also exported to countries such as Japan and Korea. The timeline of technological availability suggested in the National Biomass Strategy 2020 is as shown in Figure 2.1-1.

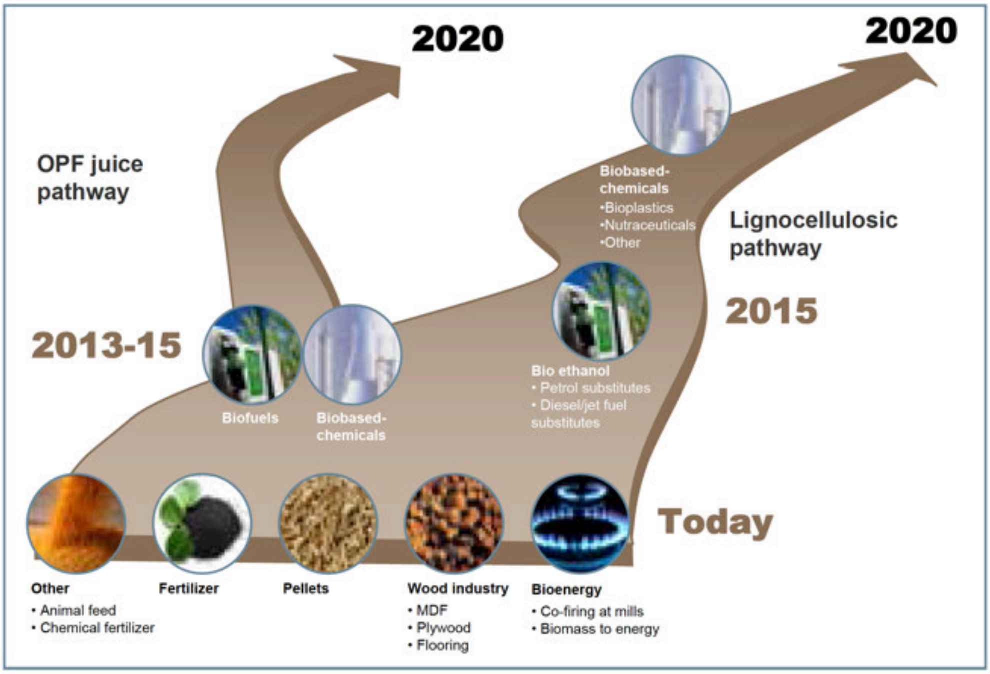


Figure 2.1-1 Technology development of bioenergy from 2013 to 2020
(Source: Rozario, 2013)

2.1.2 Applications in Malaysia

Bioenergy resources in Malaysia can be categorised into five main sources, which are, oil palm, wood, rice, sugarcane and municipal (Figure 2.1-2).

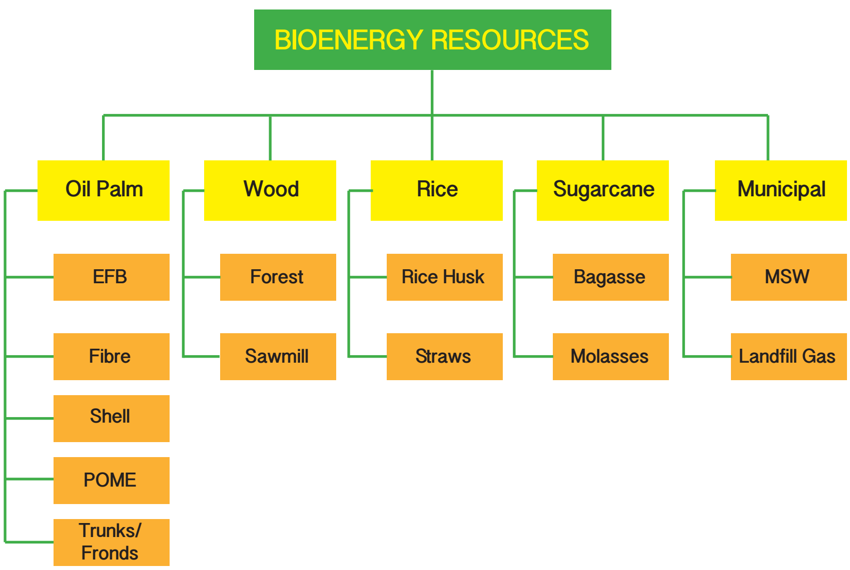


Figure 2.1-2 Bioenergy Resources in Malaysia

Biorefinery Complex at Universiti Putra Malaysia (UPM) is a research centre that practises the concept of zero emission and "waste-to-wealth" that is able to produce biocompost, biochar, biodiesel and biogas. The process is shown in Figure 2.1-3.

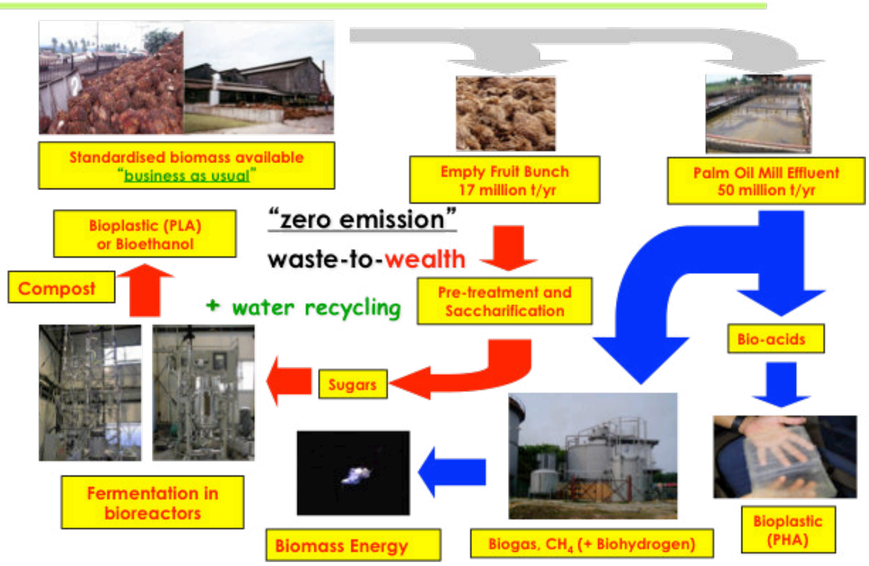


Figure 2.1-3 The "Waste-to-Wealth" concept at the Biorefinery Complex of Universiti Putra Malaysia (UPM)

In Malaysia, bioenergy applications are mainly for electricity generation, whether for in-house consumption or grid-connected systems. The TNB Jana Landfill, Puchong is the first grid-connected RE project in Malaysia that was commissioned in April 2004. The biogas is captured from a landfill area with an installed capacity of 2 MW (Figure 2.2-4). On the other hand, TSH Bio Energy Project, which is located in Kunak, Sabah has been using oil palm residues such as empty fruit bunches (EFB), palm-kernel shells (PKS) and mesocarp fiber (MF) to generate electricity. 10 MW of the 14 MW total generation capacity is sold to the SESB power utility, and is equivalent to an emission avoidance of 40 to 50 kton CO_2 per year.

Figure 2.1-4 TNB Jana Landfill, Puchong captures biogas for electricity generation

2.1.3 The Potential of Technologies

Due to high sunlight intensity and rainfall, there are abundant bioenergy resources available in Malaysia throughout the year (Table 2.1-1), which gives a total potential of about 665 MW installation capacity per year. The palm oil sector is the largest contributor, generating the largest amount of biomass, estimated at 83 million dry tonnes in 2012, and is expected to increase to about 100 million dry tonnes by 2020 (PEMANDU 2014).

An example of potential power generation from palm oil residues is shown in Table 2.2-2. About 17 Mtonnes and 39 Mtonnes of solid and POME, respectively, can be generated from 60 Mtonnes of palm oil production, and this is equivalent to a total of 2,400 MW electricity generation capacity. Moreover, bottled biogas can also be used as cooking gas.

Table 2.1-1 Potential of annual electricity generation from bioenergy in Malaysia

Sector	Quantity kton/yr	Potential annual generation (GWh)	Potential capacity (MW)
Rice Mills	424	263	30
Wood Industries	2177	598	68
Palm oil mills	17980	3197	365
Bagasse	300	218	25
POME	31500	1587	177
Total	72962	5863	665

(Source: MPOB, SIRIM, FRIM, Forestry Dept. and Ministry of Agriculture)

Table 2.1-2 An example of electricity generation from the oil palm industry

Type of industry	Production (thousand tonne)	Residue	Residue product ratio (%)	Residue generated (thousand tonne)	Potential energy PJ	Potential electricity generation (MW)
Oil palm	59,800	EFB at 65% MC	21.1	12,642	57	520
		Fiber	12.7	7,607	108	1032
		Shell	5.7	3,391	55	545
	Total Solid		16,671	220	2098	
	POME(3.5m3/CPO or 65% of FFB)		38,870		320	

(Source: Malaysian Oil Palm Statistics, 22nd Edition, MPOB)

Biomass used in higher value products such as fuels and chemicals is relatively a new industry globally, and this is a unique opportunity for Malaysia to be at the forefront. Recent announcements of commercial scale second-generation biofuel production have accelerated predictions of technology maturity, with global production expected to begin by 2015. In order to fully capitalise on this biomass opportunity, an additional 20 million tonnes of biomass compared to a business as usual scenario could be deployed towards higher value downstream activities such as pellets, bioethanol and bio-based chemicals. This represents a possible GNI increase of RM30–34 billion by 2020 and the creation of 66,000 jobs (NBS). Therefore, energy efficiency at palm oil mills utilising biomass for steam and electricity need to be improved to get higher outputs, so that with the same amount of inputs, part of the biomass can be freed for higher value non-energy products (Figure 2.1-5).

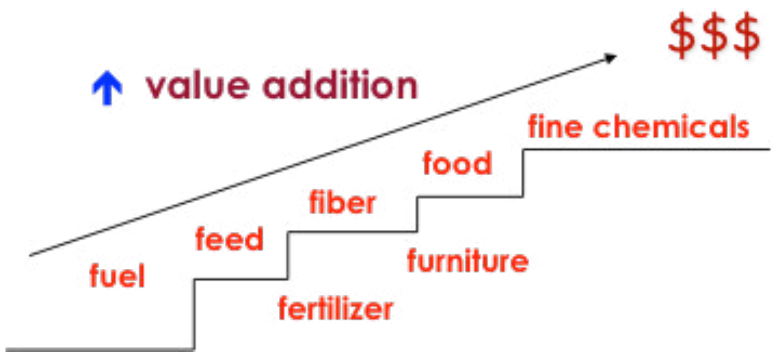


Figure 2.1-5 Added values of biomass from the oil palm industry

2.1.4 Initiatives in Malaysia

The National Biomass Strategy (NBS) 2020 was established in 2013 and plays an instrumental role in enabling Malaysia to capture opportunities in this sector (Rozario, 2013). NBS 2020 aims to assess and inform stakeholders on how Malaysia can develop new industries and high-value opportunities by utilising agricultural biomass for high value products. This will help catapult Malaysia to the forefront of the development of new biomass-based industries, ultimately contributing towards Malaysia's GNI and high-value job creation.

In addition, "palm oil and rubber" has been identified as one of the National Key Economic Areas (NKEAs) of the Economic Transformation Programme (ETP). The fifth Entry Point Project (EPP) of this NKEA, "Developing Biogas Facilities at Palm Oil Mills" encourages palm oil millers to use biogas-trapping facilities to capture methane, a greenhouse gas that can also be used as renewable energy. Thus, biogas from a total of 434 palm oil mills is targeted to generate grid-connected electricity.

2.2 Geothermal

2.2.1 State of the Art

Geothermal extracts heat stored in the earth. In order to extract this heat, hot spots need to be identified. A hot spot is a place where groundwater collected over the years is heated up by magma and becomes hot fluid stored under the ground. Then, a well with a depth of 1 to 2 km is drilled into the ground. Due to the pressure difference, hot water will flow up through the pipe. Some of the hot fluid becomes steam and some that goes to the wellhead separator becomes instantly vaporised.

The hot fluid that is not flushed into steam in the wellhead separator then goes to a standard-pressure crystalliser and is turned into standard pressure steam. The remaining hot fluid goes to a lower pressure generator, which produces low-pressure steam. Finally, all the low-pressure, high-pressure and standard-pressure steam is transferred to a turbine, which converts geothermal energy into mechanical energy. The force and energy of the steam spins the turbine blades that turn a shaft, which is directly connected to an electrical generator. The generated electricity is then transferred to a transformer before it is sent to power lines (Figure 2.2-1).

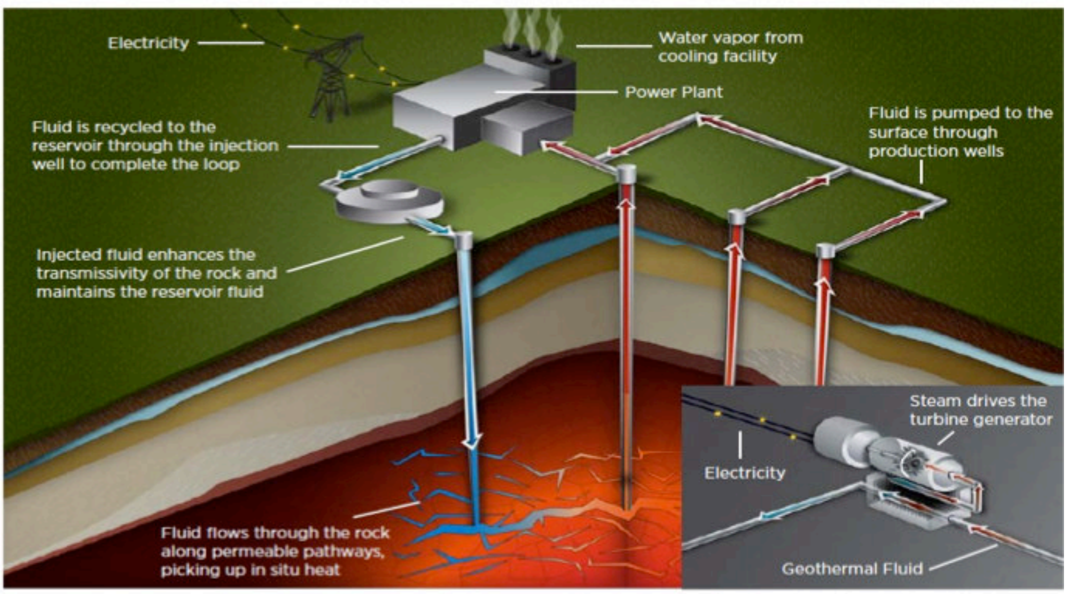


Figure 2.2-1 Geothermal power plant

There are three types of geothermal power plants:

i) Dry Steam:

As shown in Figure 2.2-2a, dry steam, which acts as heat source moves through the turbine and then through the condenser to form water and is injected back to the reservoir.

ii) Flash Steam:
Due to a decrease in pressure, the extremely hot fluid is turned or "flashed" into steam, and this heat energy is then used to turn the turbine (Figure 2.2-2b).

ii) Binary Cycle:
The hot fluid is used to heat up another working fluid such as isobutane in a closed loop system through a heat exchanger. As this working fluid has a lower boiling point, it turns into steam faster and at a lower temperature. The steam then is used to turn the turbine (Figure 2.2-2c). This is also the system that has been proposed for Tawau's geothermal power plant in the future.

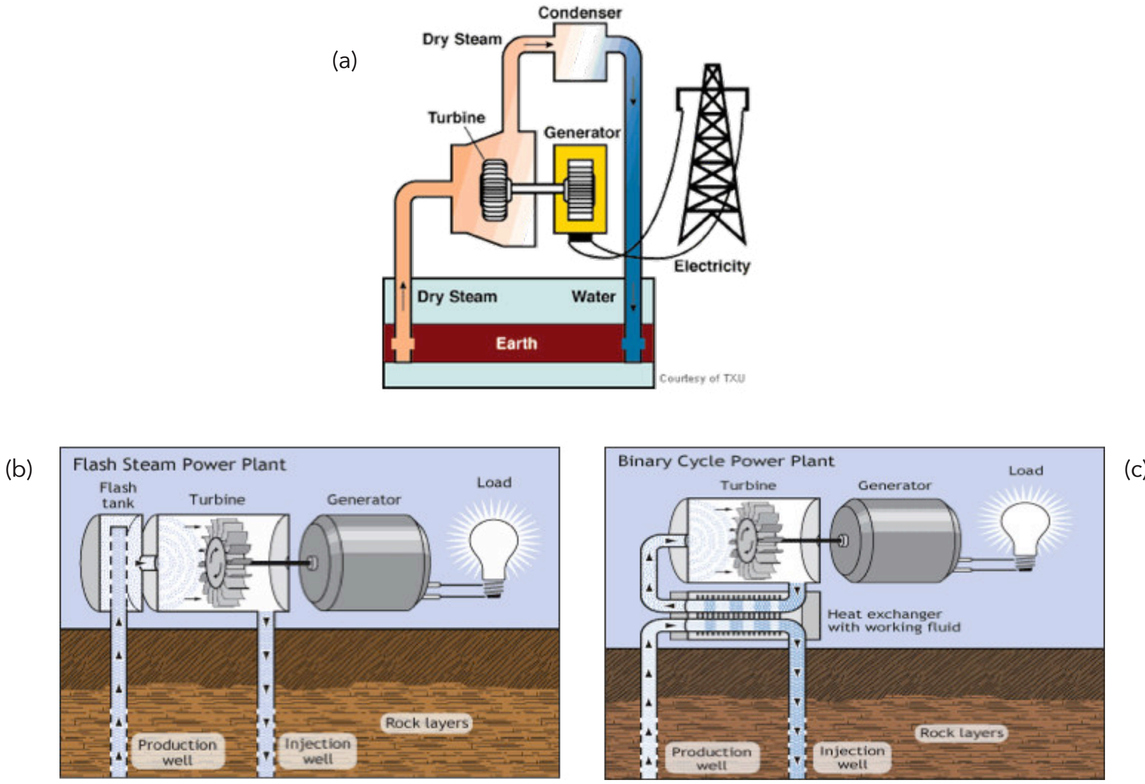


Figure 2.2-2 Geothermal power plants with (a) dry steam; (b) flash steam; and (c) binary cycle

2.2.2 Applications in Malaysia

Currently geothermal electricity is not available in Malaysia.

2.2.3 The Potential of Technologies

Tawau in Semporna Peninsula, Sabah presents a potential area for geothermal energy development in Malaysia. The volcanic rocks of andesitic and dacitic composition form a line of composite volcanoes from Mount Magdalena to Mount Wullersdorf in Tawau and Mount Pock in Semporna. Chemical analysis of the volcanic rocks has been carried out to identify whether the identified spot is associated with volcanic activity.

The potentiality of the geothermal resource in Tawau for energy was explored and numerous characteristics have been evaluated. Promising thermal manifestations like hot springs, seepages and old steaming grounds have been located at the Apas Kiri area (Figure 2.2-3). This manifestation is closely related to fracture zone of the area that is structurally controlled by the orientation of lineament system in the peninsula. Hence, these geological conditions could be suitable for the production of geothermal energy. In addition, the geothermal system of the area is considered to be dominated by hot water with a total heat loss of 28.65 MW thermal (geochemical analysis).

Apart from that, coherent negative anomalies have been detected, where the north and west of the known steam field are considered to be areas of potential. These anomalies all occur along faults or fault intersections identified from geological mapping, gravity and magnetic data, and are thought to indicate fluid upflow zones. This evidence supports the occurrence for a primary hot-water reservoir.

The thermal fluids delivered along the major structures feed the steam cap located nearby. Stratigraphically, there are two hot-water reservoir layers that can be considered, which act as the aquifer, namely the Middle Miocene sandstone facies of the Kalumpang Formation and the thick Quaternary pyroclastic layer. Both layers are intersected by deep fault systems connecting between the heat source and the ground surface. Thus, this provides for a possible and promising source of geothermal energy for future electricity supply for the local residents.

Figure 2.2-3 Study area of Apas Kiri

The first magnetotelluric investigation of the Tawau geothermal potential was carried out in 2010 to locate the geothermal system deep below the surface. A recent geoelectrical survey that was carried out in 2013 found that the Apas Kiri area has a hot water source at a shallow depth. The survey used the pole-dipole method for deeper penetrations to look at the vertical and lateral variations. The hot water with a temperature of 79°C at the surface is a potential alternative source for future electricity generation. Currently, the Tawau Geothermal Energy (TGE) is exploring further to exploit possible electricity potential based on the above data.

Its geological, geophysical and geochemical values are suitable for the production of electricity. However, further investigation is needed to identify the economic prospect. Environmentally, there exists present technology that can exploit this resource, although cost effectiveness should be well defined. The amount of geothermal energy utilised in the future will depend upon the cost and environmental concerns associated with traditional sources of energy, rather than the limits of the geothermal resource. As supplies of fossil fuels dwindle, or the impacts of global warming and acid rain become more severe, geothermal energy will become an attractive option for supplying heat and electricity in the future.

2.2.4 Initiatives in Malaysia

The state government of Sabah has initiated this exploration which was granted to Tawau Geothermal Energy (TGE), with Universiti Malaysia Sabah (UMS) as the research partner. This initiative may contribute to the technology commercialisation in the long run.

2.3 Hydropower

When water from a higher elevation is channelled to a turbine located at lower elevation via flow conduit, the potential energy of the water from higher elevation is converted into mechanical energy to rotate the shaft of the turbine. The shaft that is coupled with AC generator will then generate AC supply by converting mechanical energy into electricity (Figure 2.3-1). Conventional big scale hydropower plants commonly consist of four major components:

i) Dam:
Raises the water level of the river to create falling water, controls the flow of water and creates water reservoir that serves as stored energy.

ii) Turbine:
The force of falling water pushing against turbine blades causes the turbine to spin. and this yields mechanical energy.

iii) Generator:
Connected to the turbine by shafts and possibly gears so that when the turbine spins it causes the generator to spin as well. This converts the mechanical energy from the turbine into electrical energy.

iv) Transmission lines:
Conducts electricity from the hydropower plant to end-users.

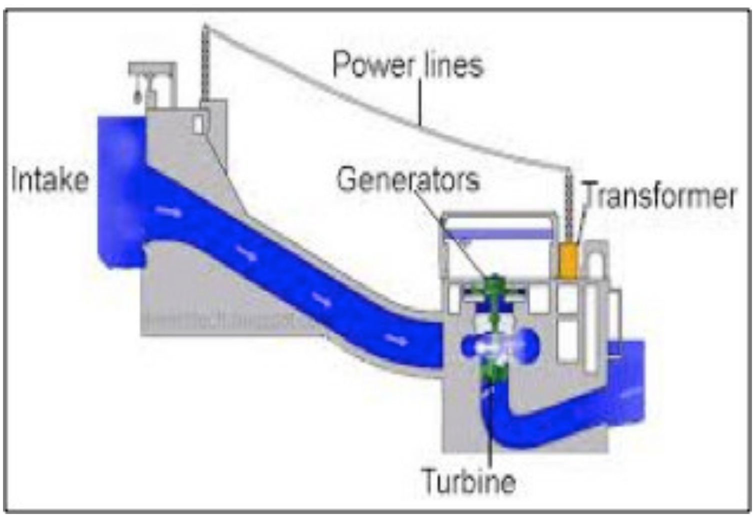


Figure 2.3-1 Schematic diagram of conventional major hydropower plant

2.3.1 State of the Art

Hydropower Technology: Energy Conversion Techniques

There are two types of turbines that convert the potential energy of water into the kinetic energy of the rotating shaft, namely impulse and reaction turbines.

i) Impulse turbines

Potential energy is converted to fully kinetic before hitting turbine buckets via high velocity water jets, whereby the jet stream is at ambient air pressure and the turbine bucket is rotating in the air. The velocity diagram of the turbine is as shown in Figure 2.3-2.

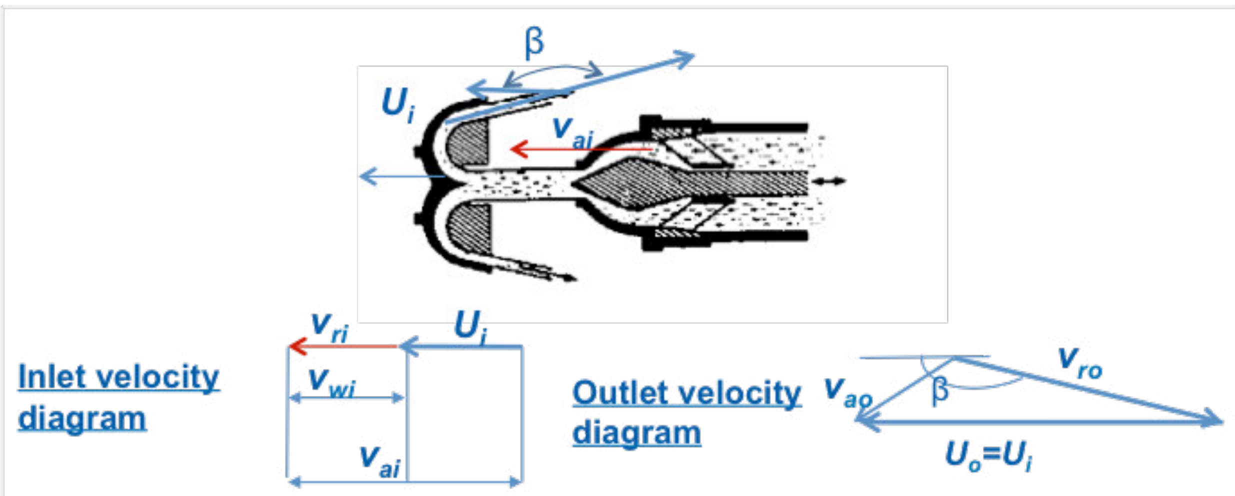


Figure 2.3-2 Velocity diagram of impulse turbine
(*U_i=bucket linear velocity; V_a= jet absolute velocity; V_r = jet relative velocity; V_w= peripheral velocity; i=inlet; o= outlet*)

The power developed by the bucket can be calculated using Equation (2.3-1) as follows:

Power developed by bucket = $\rho Q U_i (v_{ai} - U_i) * (1 - k Cos\beta)$ Eq. (2.3-1)

Whereby k = bucket friction factor; k=1.000 for lossless scenario; *Q=volumetric flow rate of the jet stream*

Maximum theoretical power developed by the buckets occurs if (1) $U_i = 0.5 v_{ai}$,(2) $\beta = 180^o$ and (3) $k=1.00$

Figure 2.3.3 shows examples of impulse turbines such as Peltron, Turgo and Crossflow.

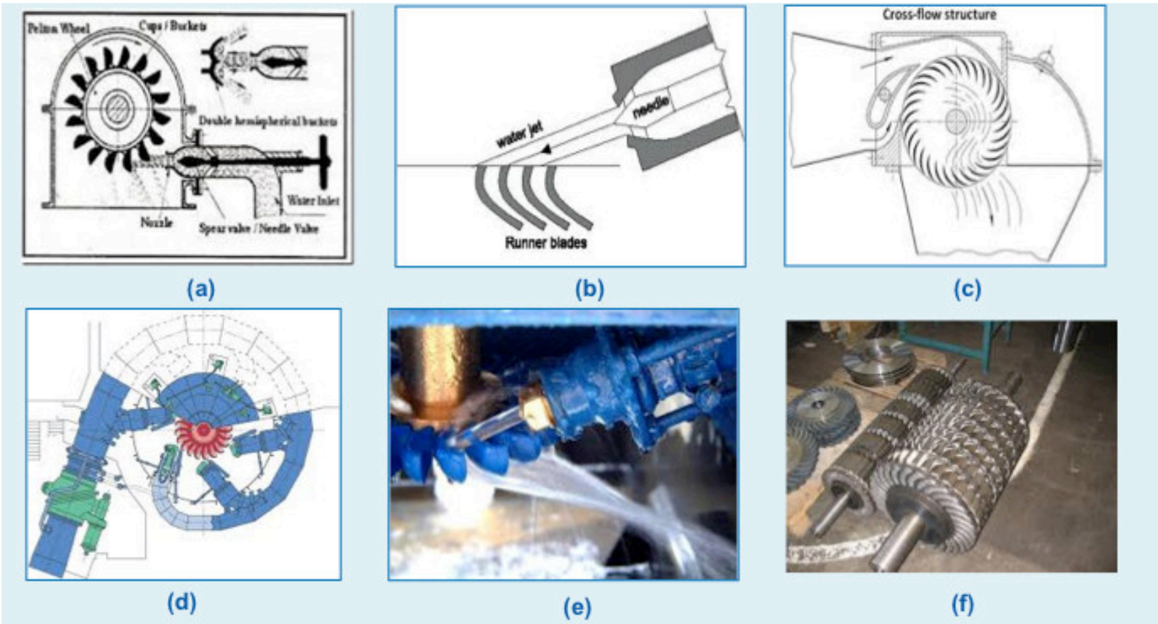
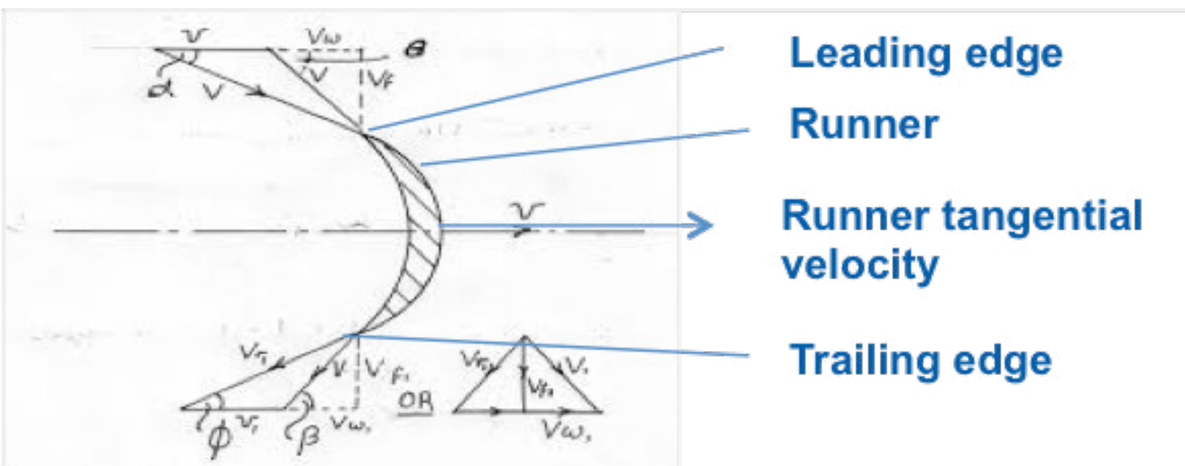


Figure 2.3-3 (a) Pelton turbine jet stream and bucket; (b) Turgo turbine jet stream and bucket; (c) Schematic diagram for cross turbine; (d) Plan view for multi-jet Pelton turbine (e) Turgo turbine; and (e) Cross flow turbine

ii) Reaction turbines

When the water is travelling across the runners, the potential energy is changed to kinetic energy, whereby the turbine runner will rotate in the water. The velocity diagram is shown in Figure 2.3-4 and the power developed by runners can be calculated by Equation (2.3-2) as follows:

$$P = \rho Q U_{turb} (U_i v_{wi} - U_o w_o) \qquad \text{Eq. (2.3-2)}$$



Note: U_i is not equal to U_o

Figure 2.3-4 Velocity diagram of reaction turbine

Figure 2.3-5 shows some examples of the reaction turbines such as Francis, Kaplan, Dariaz, propeller and Bulb.

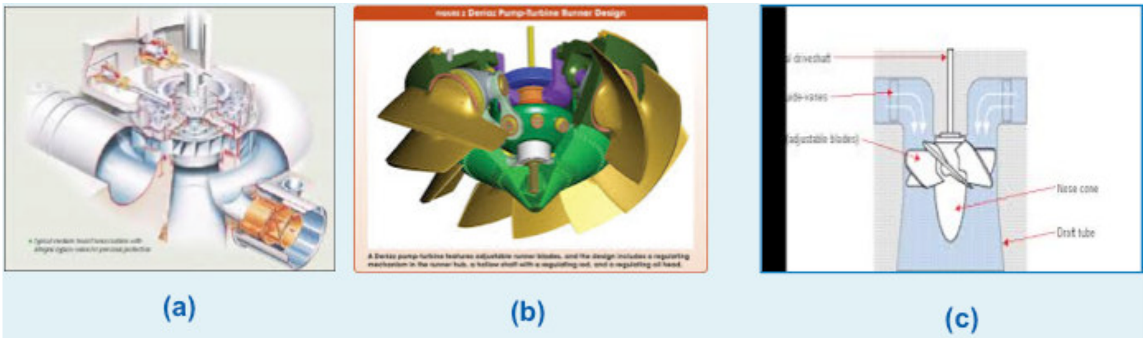


Figure 2.3-5 (a) Vertical Francis turbine (>80% of installed capacity); (b) Vertical Dariaz turbine; and (c) Vertical Kaplan turbine

Hydropower Technology: Turbine Selection

Turbine selection depends on the site conditions. There are two parameters that cannot be altered : 1) the availability of water, which is determined by average rainfall over the catchment area; and 2) the available head. Next is matching the site with the turbine type based on the specific speed (η_s) of the turbine.

The specific speed is the speed with which the turbine turns for a particular discharge Q, with unit head and thereby is able to produce unit power. Figure 2.3-6 shows one of the examples of turbine selection options based on the available head and specific speed.

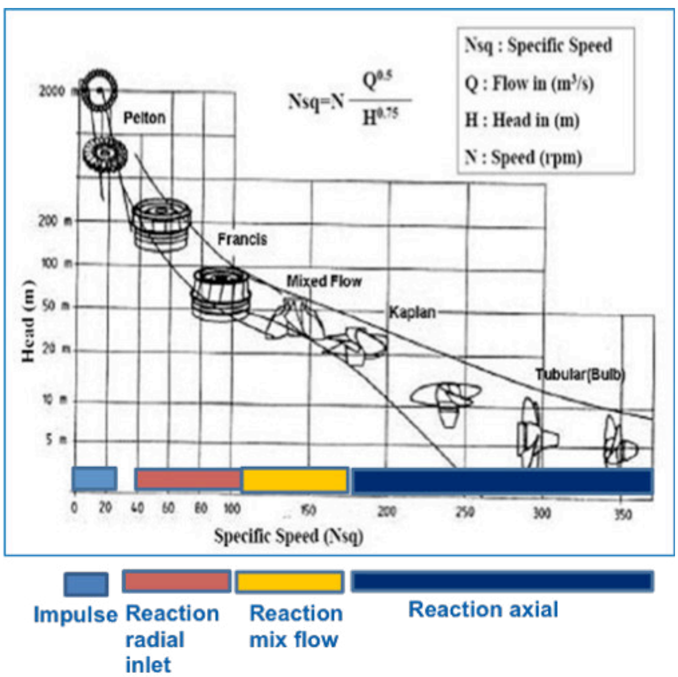


Figure2.3-6 N_{sq} versus types of turbines to be selected

Hydropower Technology: Storage Sizing

Storage could be no live storage at all, e.g. run-of-the-river. The storage capacity can be used for hours, months, yearly or even two years. The higher reliability of supply is required, the bigger the live storage needs to be made available during the design stage. Bigger live storage offers added value to the hydropower plants because of more efficient water management and ability in flood control. As such, the storage serves as a multi-purpose reservoir and not solely for power generation. The biggest storage in Peninsula Malaysia is the SJ Kenyir reservoir whereby its maximum live storage is about 13 months of annual average rainfall (Figure 2.3-7). Table 2.3-1 shows the storage capacity of some of the hydropower plants in Malaysia.

Figure 2.3-7 SJ Kenyir reservoir

Table 2.3-1 Storage capacity of some of the hydropower plants in Malaysia

Power Plant	Installed capacity (MW)	Annual Yield (GWh)	Storage equivalent1 (%)	Power Plant
SJ Chenderoh	35	248	Cascade	SJ Chenderoh
SJ Sultan Yussof, Jor	100	380	Days	SJ Sultan Yussof, Jor
SJ Sultan Idris II, Woh	150	480	Weeks	SJ Sultan Idris II, Woh
SJ Temengor	348	863	Months	SJ Temengor
SJ Sultan Azlan Shah, Bersia	72	237	Cascade	SJ Sultan Azlan Shah, Bersia
SJ Sultan Azlan Shah, Kenering	120	457	Cascade	SJ Sultan Azlan Shah, Kenering
SJ Sultan Mahmud Shah, Kenyir	400	1600	13 months	SJ Sultan Mahmud Shah, Kenyir
SJ Piah Lower	15	80	Run-of-the-river	SJ Piah Lower
SJ Piah Upper	55	300	Run-of-the-river	SJ Piah Upper
SJ Pergau	150	520	Weeks	SJ Pergau
SJ Tenom Pangi, Tenom	66	480	Hours	SJ Tenom Pangi, Tenom
SJ Batang Ai, Sarawak	20	611	NA	SJ Batang Ai, Sarawak
SJ Bakun	2400	15500	One year	SJ Bakun

[1] Storage equivalent is measured by how long its storage can last under full capacity operation assuming no incoming flow; for cascade type of hydropower plants, the measure is based on their main reservoir

2.3.2 Applications in Malaysia

Cameron Highlands –Batang Padang hydro schemes were developed in the 1960s, followed by the construction of two major hydropower plants, i.e. SJ Sultan Yussof (100 MW) and SJ Sultan Idris II (150 MW). Then, another four mini hydropower plants were built, i.e. SJ Odak, SJ Kuala Terla, SJ Habu and SJ Robinson Fall with a total capacity of less than 15 MW. After the oil crisis in the 1970s, another three major installations were added : SJ Temengor, SJ Bersia and SJ Kenering. Later, with the increase in electricity demand, a few more hydropower plants were built between 1988 and 2000, i.e. SJ Sultan Mahmud, Kenyir, SJ Piah (Upper & Lower) and SJ Sultan Ismail Petra, Pergau.

Table 2.3-2 shows the capacity and annual yield of some of the major hydropower plants in Malaysia. Based on the CO_2 Emission Factor of 0.741kg/kWh, these plants are able to reduce up to 4.64 million tonne CO_2/annum, and the reduction will be greater if SJ Bakun is included.

Table 2.3-2 Installed capacity and annual yield of some of the major hydropower plants in Malaysia

Power plant	Locations	Turbine types	Number of units	Installed capacity (MW)	Annual yield (GWh)	Capacity factor (%)
SJ Chenderoh	K Kangsar	Vertical Francis	4	35	248	80.8
SJ Sultan Yussof, Jor	Cameron Highlands	Vertical Pelton	4	100	380	43.3
SJ Sultan Idris II, W oh	Cameron Highlands	Vertical Francis	3	150	480	36.5
SJ Temengor	Grik	Vertical Francis	4	348	863	28.3
SJ Sultan Azlan Shah, Bersia	Grik	Vertical Kaplan	3	72	237	37.6
SJ Sultan Azlan Shah, Kenering	Kenering	Vertical Francis	3	120	457	43.4
SJ Sultan Mahmud Shah, Kenyir	Kuala Berang	Vertical Francis	3	400	1600	45.6
SJ Piah Lower	Sg Siput	Horizontal Pelton	2	15	80	60.8
SJ Piah Upper	Sg Siput	Vertical Pelton	2	55	300	62.2
SJ Pergau	Jeli	Vertical Francis	4	150	520	10
SJ Tenom Pangi, Tenom	Tenom Pangi	Vertical Francis	3	66	480	83

Power plant	Locations	Turbine types	Number of units	Installed capacity (MW)	Annual yield (GWh)	Capacity factor (%)
SJ Batang Ai, Sarawak	Sarawak	Vertical Francis	4	20	611	348.5
SJ Bakun	Sarawak	Vertical Francis	8	2400	15500	NA
Total			31	1330	6256	53.66

There are a few more plants that are under construction in Peninsula : Tembat, Puah, Ulu Jelai, Lebir, Nenggiri, Sg Perlus, Telom, Tekai and Kerian with an estimated total capacity of 1,600 MW; while in Sarawak, it is expected to be more than 5,300 MW.

In terms of mini hydropower plants, there are more than 30 plants which have been developed under the scheme "Bekalan Elektrik Luar Bandar (BELB)" and are mostly owned by LLN/TNB. The total capacity of these mini hydropower plants are about 16 MW with an annual yield of less than 15 GWh.

2.3.3 The Potential of Technologies

Malaysia has a total drainage area of 332,00 km^2, with a mean elevation of 300m. Together with an annual rainfall of more than 2,600mm, these geographical features provide a theoretical hydropower potential of about 414,000 GWh/year, while the electricity consumption for the Peninsula in 2014 is only 125,000 GWh. The potential of hydropower is mainly from Sabah and Sarawak, whereas only 85,000 GWh of the potential is from the Peninsula. The main constraint of this energy is that hydropower plants are usually far from the main load centers.

The contribution of hydropower towards reducing generation cost and CO_2 emission is significant, more than 5 million tonne/annum and is expected to double over the next 10 years. One area that needs to be monitored in order to maximize CO_2 reduction from hydropower plants is the actual operational performance versus the design operational performance. Therefore, it is important to institutionalise baseline performance indicators for all hydropower plants in Malaysia based on the rated annual generation yields. At the same time, a workable auditing system may need to be developed in order to facilitate these performance improvement initiatives.

2.3.4 Initiatives in Malaysia

The total potential of hydropower resources for Malaysia has been fully identified. Besides the large-scale hydropower sites in Sarawak that are under construction, no new large-scale sites have been identified and hence, no new initiatives of hydropower have been formulated.

2.4 Nuclear Energy

Nuclear fission is either a nuclear reaction or a radioactive decay process in which the nucleus of an atom splits into smaller parts (lighter nuclei). The fission process often produces free neutrons and photons (in the form of gamma rays), and releases a very large amount of energy even by the energetic standards of radioactive decay. The chemical element isotopes that can sustain a fission chain reaction are called nuclear fuels, and are said to be fissile.

All fissionable and fissile isotopes undergo a small amount of spontaneous fission, which releases a few free neutrons into any sample of nuclear fuel, and creates fission chain reaction. In such a reaction, free neutrons released by each fission event can trigger yet more events, which in turn release more neutrons and cause more fission (Figure 2.4-1). In the nuclear reactor, the rate of fission is controlled using control rods made of materials that absorb neutrons (e.g. boron, cadmium and silver), thus controlling the amount of neutrons available for the fission process.

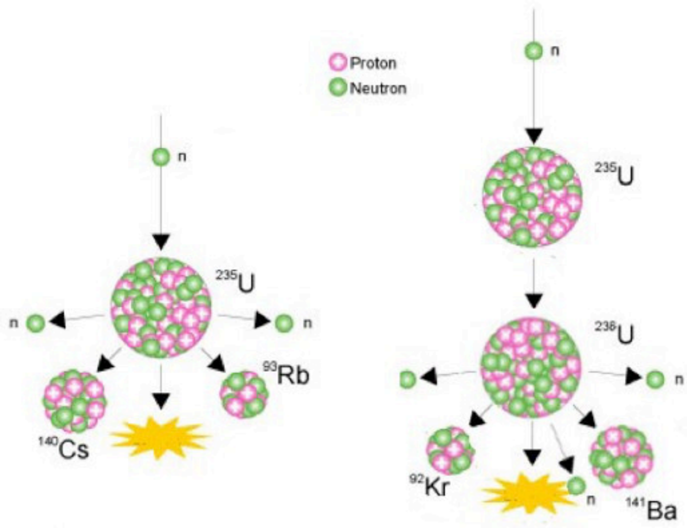


Fig 2.4.1 Two pathways for the fission of ^{235}U

Source: World Nuclear Association

The most common nuclear fuel is U-235, a fissile isotope that occurs in nature in large quantities, whereby approximately 0.74% of natural uranium is U-235 and the remainder is U-238. U-235 is commonly used in nuclear reactors. A uranium-235 atom absorbs a neutron and fissions into two new atoms (fission fragments), releasing three new neutrons and some binding energy. The "best" neutrons to be absorbed by U-235 are slow-moving or "thermal" neutrons. Approximately 84% of the thermal neutrons absorbed by a U-235 nucleus will cause fission. Each fission event, depending on the pathway, releases 2 to 3 new fast neutrons with approximately 2MeV energy (Figure 2.4.1). On average, one fission event releases about 2.43 new fast neutrons. In the light water reactor, the fast neutrons are slowed down or thermalised by the water surrounding the reactor core. For a light water reactor, the U-235 content of the fuel is increased from 3.5% to 5% through a process called enrichment.

Therefore, nuclear fission is used to produce energy for nuclear power. Nuclear fuels undergo fission when struck by fission neutrons, and in turn, emit neutrons when they break apart. This makes possible a self-sustaining nuclear chain reaction that releases energy at a controlled rate in a nuclear reactor. The amount of free energy contained in nuclear fuel is a million times the amount of free energy contained in a similar mass of chemical fuel such as gasoline, making nuclear fission a very dense source of energy.

2.4.1 State of the Art

Nuclear power is a mature technology. The nuclear reactors for the production of electrical energy were developed in the 1950s and have been continuously improved to the present. Furthermore, when taking into account the life cycle, nuclear power is considered among the lowest contributor to the greenhouse gas emissions (Figure 2.4-2).

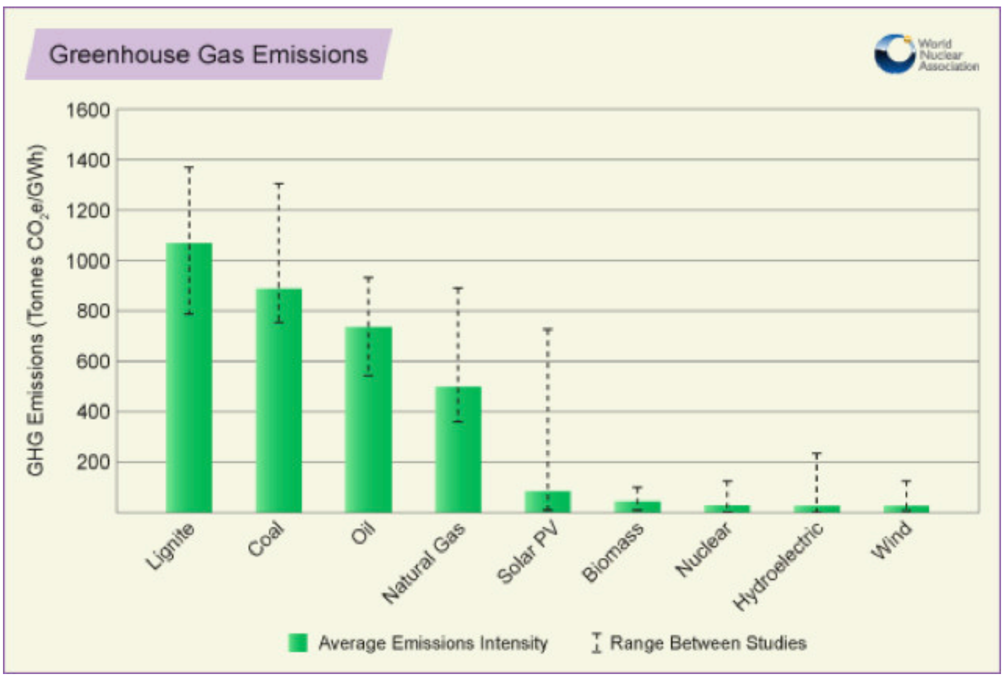


Figure 2.4-2 Comparative GHG Emissions of Power Sources
Source: World Nuclear Association

According to World Nuclear Association, in some countries, a large portion of their electricity is generated using nuclear reactors. Some of the notable ones are: France (75%), Sweden (40%), Bulgaria (35%), Hungary (30%), South Korea (30%), United States of America (19%) and Germany (18%). Further details are shown in Figure 2.4-3. Some other countries that are opting for nuclear power in the near future include the United Arab Emirates and Saudi Arabia. On the other hand, China is embarking on accelerating the expansion of her nuclear power capacity and reducing her coal plants in order to reduce her greenhouse gases loading.

Types of Commercial Nuclear Reactors

Pressurised Water Reactor (PWR)

This is the most common type, with over 230 in use for power generation and several hundred more employed for naval propulsion. The design of PWRs originated as a submarine power plant. PWRs use ordinary water as both coolant and moderator. The design is distinguished by having a primary cooling circuit which flows through the core of the reactor under very high pressure, and a secondary circuit in which steam is generated to drive the turbine. In Russia these are known as VVER (water-moderated and cooled) types. The schematic of this type of reactor is shown in Figure 2.4-3.

A Typical Pressurised Water Reactor (PWR)

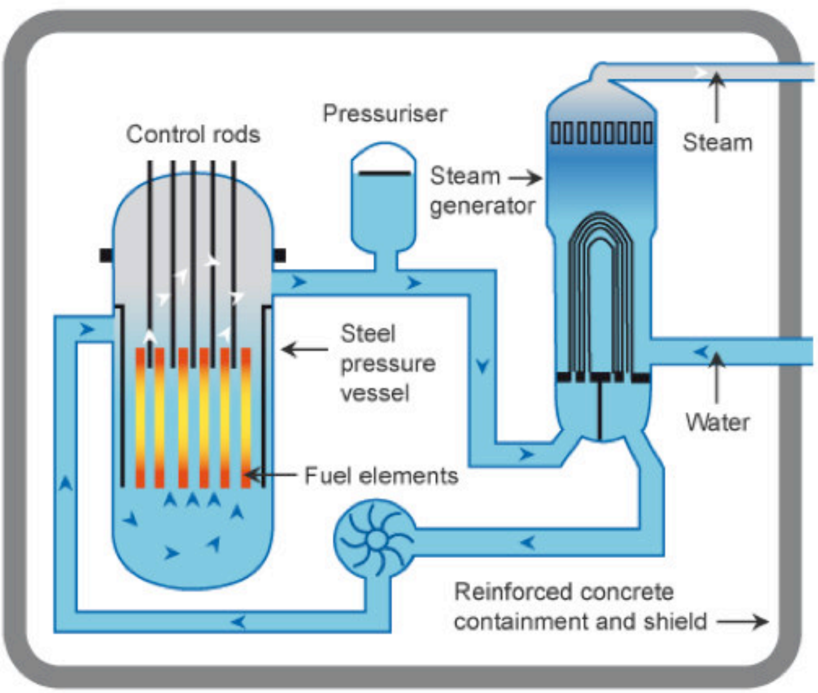


Figure 2.4-3. Schematic of a pressurised water reactor.
(Source: World Nuclear Association)

A PWR has fuel assemblies of 200-300 rods each, arranged vertically in the core, and a large reactor would have about 150-250 fuel assemblies with 80-100 tonnes of uranium. The water temperature in the reactor core reaches about 325°C, hence it must be kept under about 150 times atmospheric pressure to prevent it from boiling. Pressure is maintained by steam in a pressuriser (Figure 2.4-3). In the primary cooling circuit, water is also the moderator, and if any of it is turned to steam, the fission reaction would slow down.

This negative feedback effect is one of the safety features of the reactor. The secondary shutdown system involves adding boron to the primary circuit. The secondary circuit is under less pressure and the water here boils in the heat exchangers or steam generators. The steam drives the turbine to produce electricity, and is then condensed and returned to the heat exchangers in contact with the primary circuit.

Boiling Water Reactor (BWR)

This design (Figure 2.4.4) has many similarities to the PWR, except that there is only a single circuit in which the water is kept at a lower pressure (about 75 times atmospheric pressure) so that it boils in the core at about 285°C. The reactor is designed to operate with 12-15% of the water in the top part of the core as steam, and hence with less moderating effect and thus less efficiency there. The steam passes through drier plates (steam separators) above the core and then directly to the turbines, which are thus part of the reactor circuit. Since the water around the core of a reactor is always contaminated with traces of radionuclides, the turbine must be shielded and radiological protection is provided during maintenance work. The cost of this tends to balance the savings procured due to the simpler design. Most of the radioactivity in the water is very short-lived (mostly N-16, with a 7 second half-life), so the turbine hall can be entered soon after the reactor is shut down.

A BWR fuel assembly comprises 90-100 fuel rods, and there are up to 750 assemblies in a reactor core, holding up to 140 tonnes of uranium. The secondary control system involves restricting water flow through the core so that more steam in the top part reduces moderation.

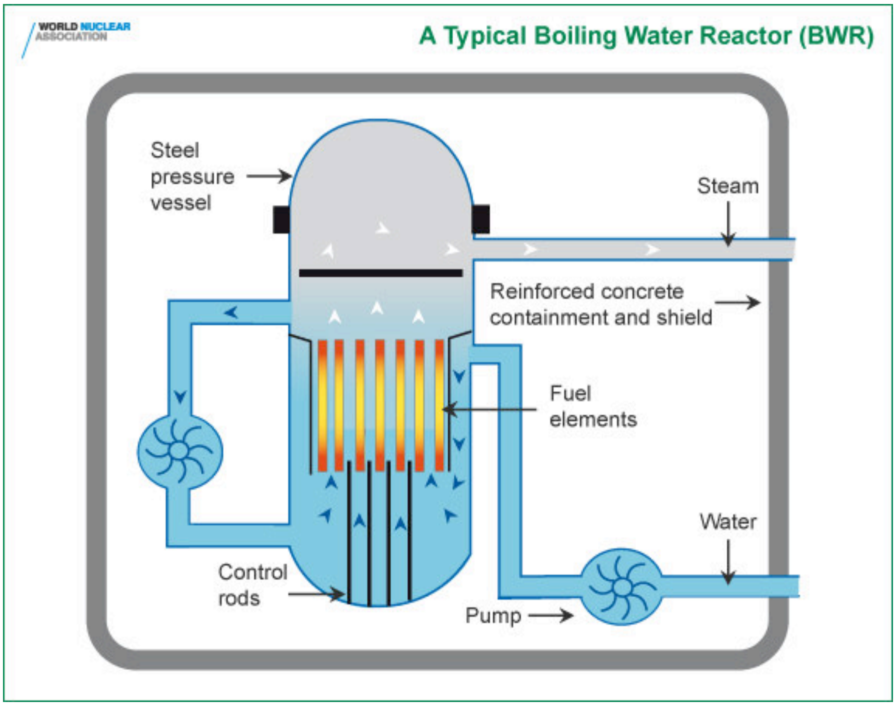


Figure 2.4-4 Schematic of a Boiling Water Reactor
(Source: World Nuclear Association)

The Power Rating of a Nuclear Power Reactor

Nuclear power plant outputs are quoted in three ways:

- Thermal MWt, which depends on the design of the actual nuclear reactor itself, and relates to the quantity and quality of the steam it produces.
- Gross electrical MWe indicates the power produced by the attached steam turbine and generator.
- Net electrical MWe, which is the power available to be sent out from the plant to the grid, after deducting the electrical power needed to run the reactor (cooling and feed-water pumps, etc.) and the rest of the plant.

The above definitions of power output are explained in Figure 2.4-5.

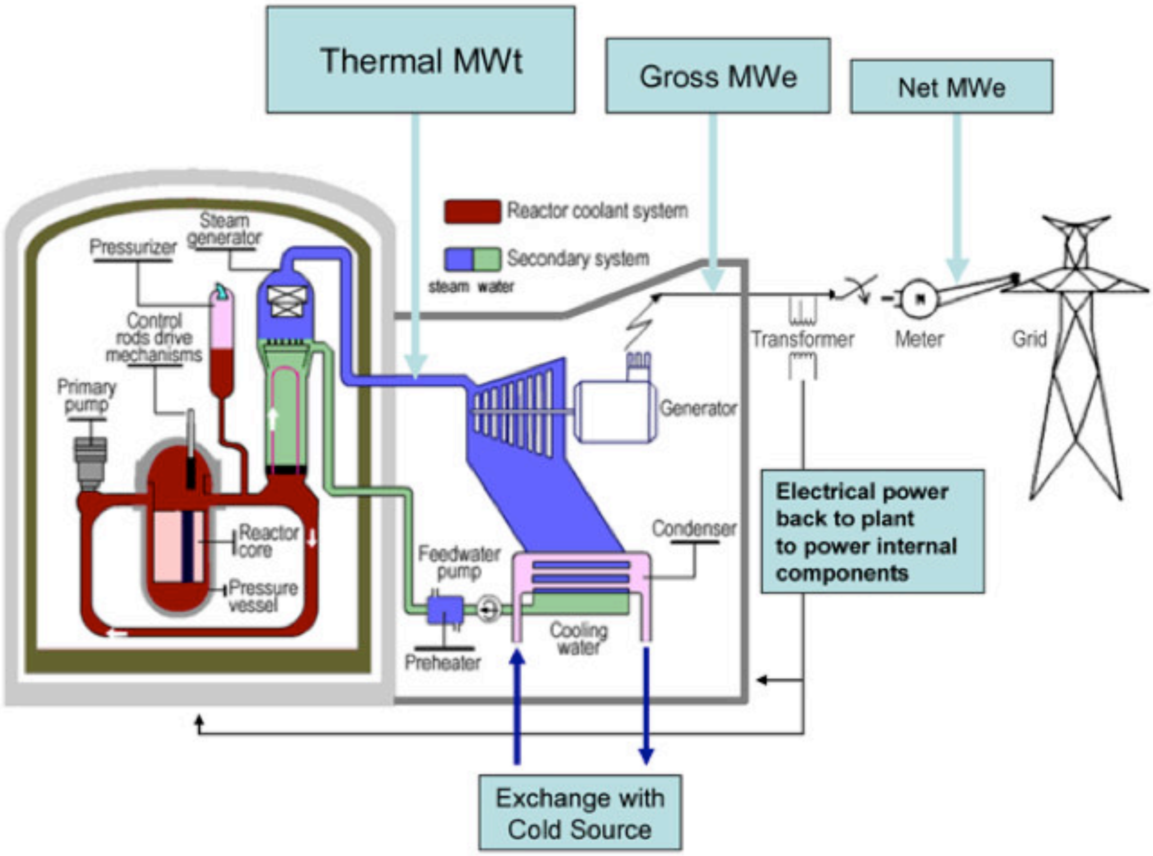


Figure 2.4-5. Definitions of the power rating of a nuclear reactor
(Source: World Nuclear Association)

2.4.2 Applications in Malaysia

Malaysia has never had a nuclear power plant (NPP). Malaysia's experience with nuclear energy is primarily with a small Triga Mark-II 1.0 MWt research reactor commissioned in 1982. Figure 2.4-6 shows the top ten countries in the world with the most NPPs installed.

GLOBAL NUCLEAR POWER STATUS

434 operable nuclear power plants in the world...

Top 10 countries most reliant on nuclear power in 2013

Country	Nuclear as % of total electricity
France	74.8
Slovakia	53.8
Slovenia	53.8
Belgium	51.0
Ukraine	46.2
Hungary	45.9
Sweden	38.1
Switzerland	35.9
Czech Republic	35.3
Finland	32.6

... and many more are planned, mostly in Asia.

Status as of 1 February 2014

Nuclear Power Plant Status:	No. of Plants:	Generating Capacity (MWe):
Operable	434	374,335
Under Construction	70	74,911
In Planning	173	186,388
Proposed	310	349,170

Top 10 countries with most nuclear projects in progress

Country	Units Operable	Units Construction	Units Planned	Units Proposed
China	20	28	58	118
Russian Fed.	33	10	31	18
India	21	7	18	39
USA	100	5	7	15
Korea (ROK)	23	5	6	0
Japan	48	3	9	3
UAE	0	2	2	10
Pakistan	3	2	0	2
Slovakia	4	2	0	1
Saudi Arabia	0	0	6	16

Source: World Nuclear Association (WNA)

MNPC

Figure 2.4-6. Global status of nuclear power

2.4.3 The Potential of Technologies

Future nuclear power could be used for diverse applications, such as water desalination and hydrogen production. Water desalination is required to safeguard future water security. Hydrogen production is needed to support the future application of hydrogen as energy carrier.

However, as noted by Malaysia Nuclear Power Corporation (MNPC), there are major challenges in the development of nuclear power (Figure 2.4-7). By far, the most daunting are public acceptance and financing. Naturally, the latter is contingent on the former as no financier will be willing to dump her/his money into a project doomed due to public resistance. Furthermore, support for and opposition against nuclear power seem to go along political party lines and no amount of public awareness campaigns is likely to close this divide. Under these circumstances, perhaps the issue has to be decided by a referendum. Once the public acceptance hurdle is surmounted, then it should to be easier to raise the necessary funds for the project.

Figure 2.4-7. MNPC's communication plans and strategies on nuclear power development

2.4 Initiatives in Malaysia

In 2009, the Malaysian Government considered nuclear energy as one of the options for electricity generation post-2020 in Peninsula Malaysia. A year later, the government adopted the National Nuclear Policy for energy and non-energy applications. A summary of the policy is shown in Figure 2.4-8.

Later on, nuclear energy was identified as one of the 12 Entry Point Projects (EPP) under the Oil, Gas & Energy Sector. Thus, Malaysia Nuclear Power Corporation (MNPC) was established in January 2011 as the Nuclear Energy Programme Implementing Organisation (NEPIO). MNPC is to lead, coordinate and implement Malaysia's nuclear energy development programme based on IAEA requirements and the ETP nuclear plan timeline. The functional structure of the MNPC is shown in Figure 2.4-9. On the other hand, Malaysia Nuclear Agency has been appointed as the Technical Support Organisation (TSO) for nuclear power development. The responsibilities of Nuclear Agency include supporting the nuclear power plant regulator, operator and local industry; carrying out research, developing and transferring new technologies; and providing the necessary expertise and advice to the Government.

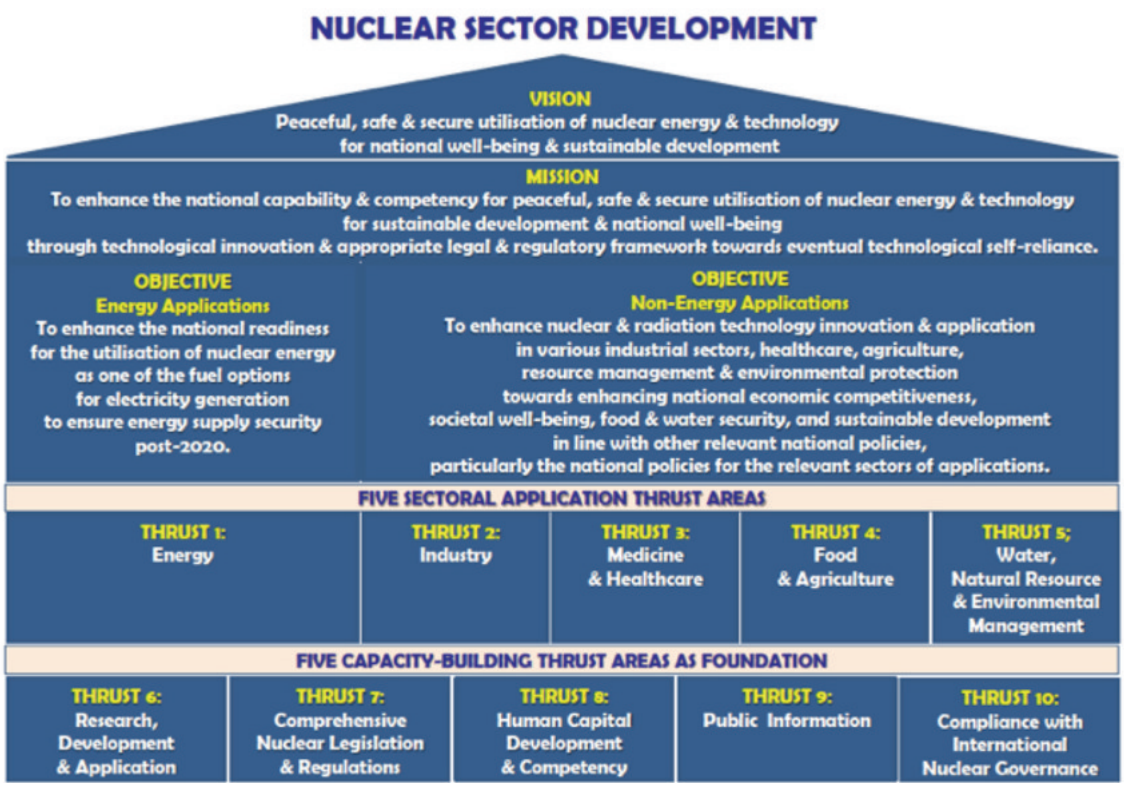


Figure 2.4-8 National Nuclear Policy

(Source: Abu, 2011)

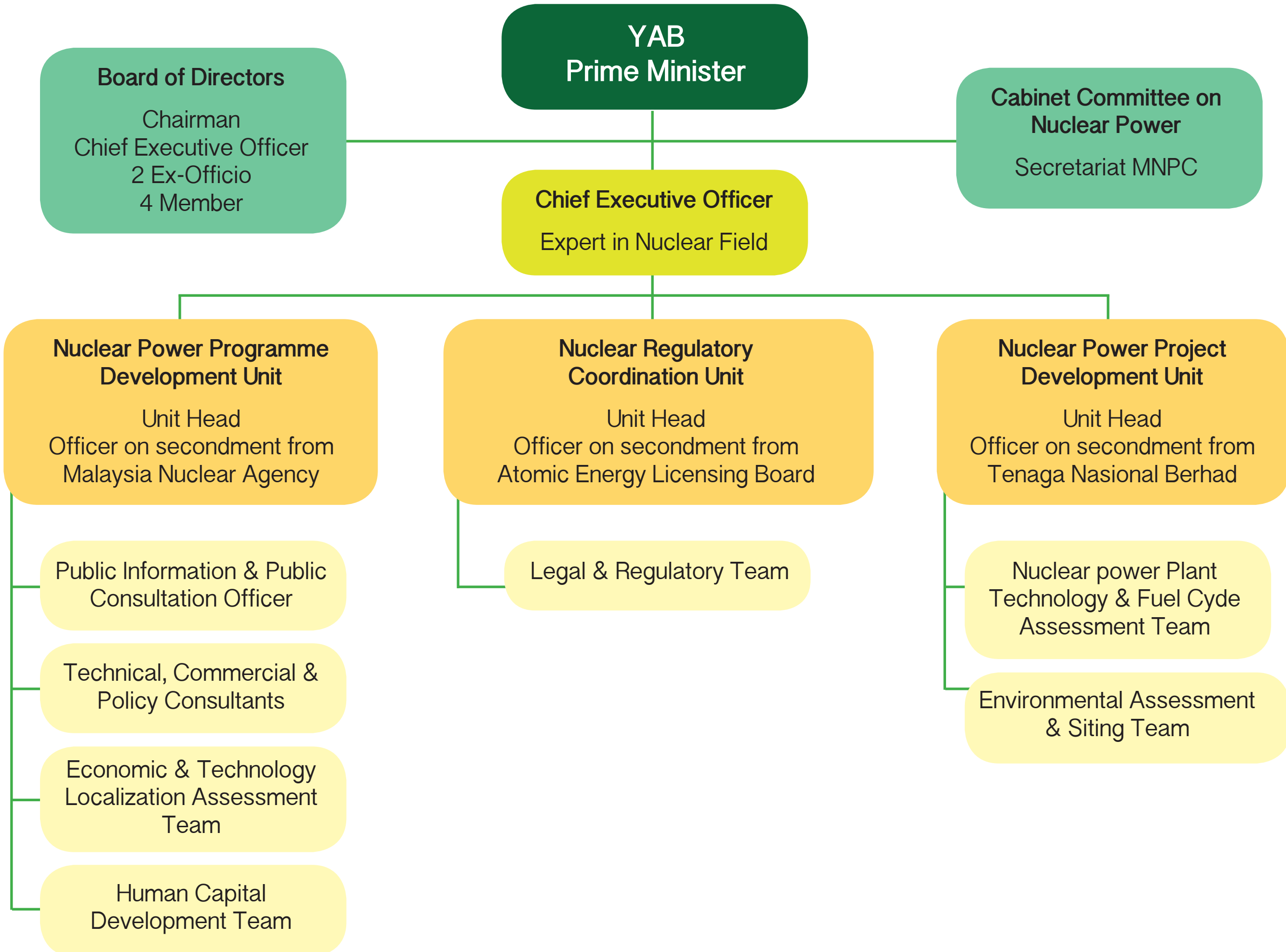
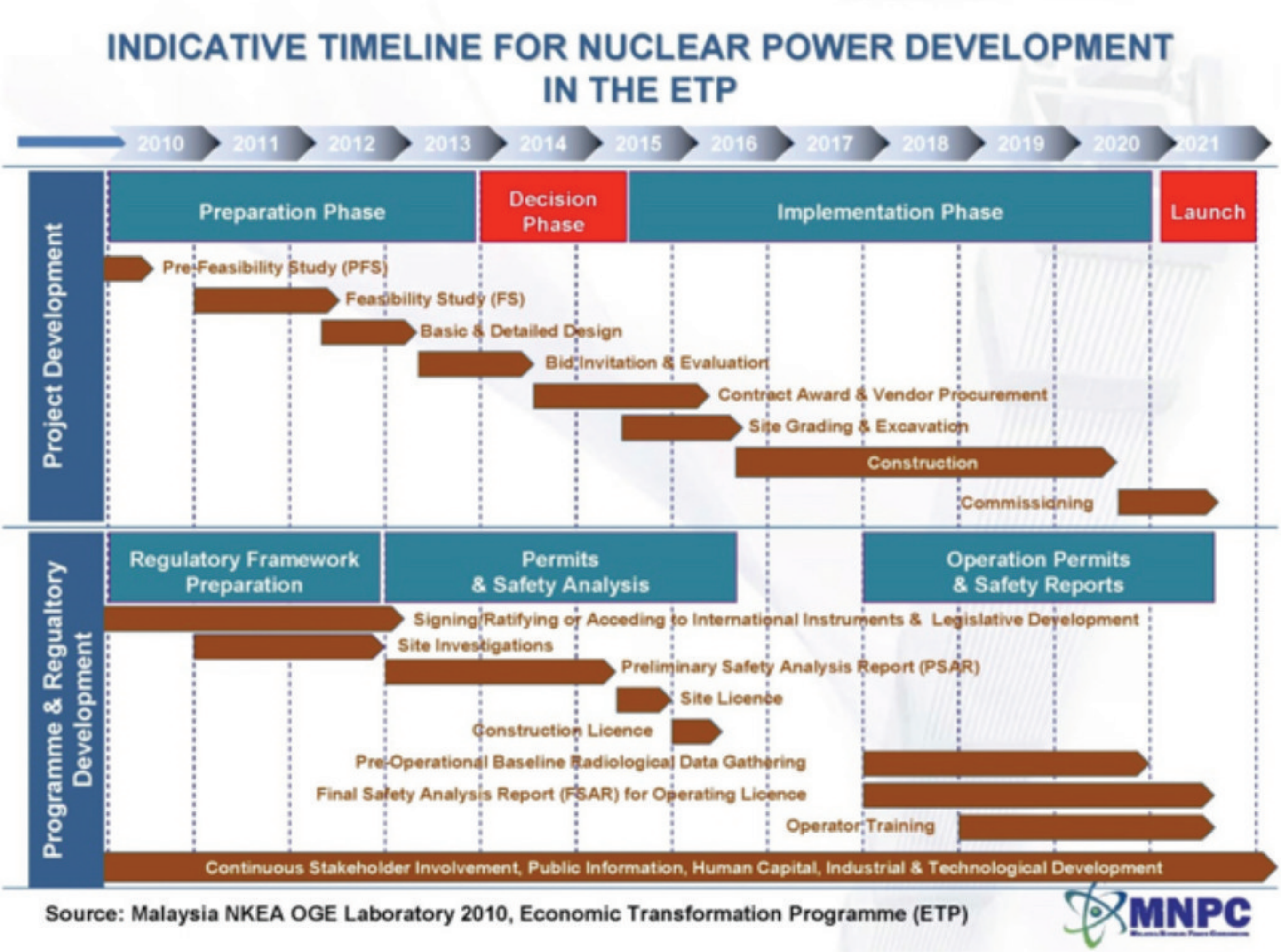


Figure 2.4-9 The functional structure of the MNPC

(Source: Abu, 2011)

In order to start deploying the commercialised nuclear power, it is envisaged that the nuclear reactors will be solely for the generation of electricity for Peninsular Malaysia. The indicative timeline (Figure 2.4-10) for nuclear power development sets the operation of the first and second nuclear power reactors to start in 2021 and 2023, respectively. The combined capacity is targeted to be 2000 MW.

All the findings from consultation activities will need to be verified by IAEA. To date, preliminary feasibility study and site selection as well as ranking have been completed. However, the site evaluations have been deferred and will only be carried out after obtaining the Government's consent to proceed, based on the results of comprehensive national public opinion and consultation on nuclear energy.



Conversion (OTEC)[1]

Ocean Thermal Energy Conversion (OTEC) by definition is "a method of converting part of the heat from the Sun, which is stored in the surface layers of a body of water into electrical energy or energy product equivalent" (US Public law 1980). Thus, ocean thermal energy is one of the six secondary sources of energy through the natural capture of the Sun's energy in the atmosphere as wind and rain for hydroelectric power, at sea as wave and oceanic current, and by photosynthesis as biomass. The principle of OTEC is illustrated in Figure 2.5-1.

[1] This Draft is prepared by Dato' Ir Dr A Bakar Jaafar, Co-Chair, UTM Ocean Thermal Energy Centre (UTM OTEC), Professor, UTM Perdana School of Science, Technology, Innovation, & Policy. E-mail: bakar.jaafar@gmail.com; Mobile: +6012 320 7201

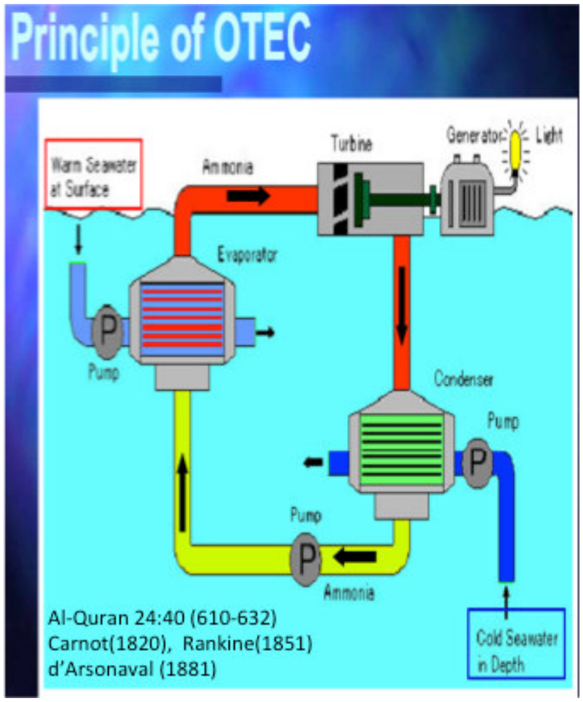


Figure 2.5-1 Principle of OTEC

The global potential of ocean thermal energy resource, in the tropic and sub-tropical regions, for power production would be in "the order of 7TW, 7,000GW, or 7 million MW; this could be achieved without much effect on ocean temperatures" (Krishnakumar and Nihous 2013). In short, if the average consumption per capita is 1 kW, the OTEC resource alone could support 7 billion people in the world.

2.5.1 State of the Art

The technique to harness energy from the warm column of the tropical seas, where a temperature differential of 20 degree Centigrade exists, was discovered by Jacques D'Arsonval in 1881. The first ocean thermal energy plant was built in Northern Cuba by Georges Claude in 1930, and the second one off Ivory Coast in 1956. After the Arab Oil Embargo in 1973, there was renewed interest to develop the technology that can convert thermal energy into electricity or other forms of energy.

Currently, there are at least seven OTEC technology providers, in alphabetical order, namely, BlueRise of the Netherlands, DCNS of France, Energy Island of UK, Korea Research Institute of Ship and Ocean Engineering (KRISO), Lockheed-Martin of USA, Technip of France, and Xenesys, Inc of Japan.

2.5.2 Applications in Malaysia

The OTEC technology has yet to be applied in Malaysia. Nonetheless, the first offshore 16 MW OTEC plant which is of commercial size is to be commissioned in the year 2018 off Martinique, the French Territory of the Caribbean region.

2.5.3 The Potential of Technologies

It is worth noting, however, that the potential of applying such available technologies in Malaysia is enormous. It has been estimated that Malaysia has the potential capacity of generating up to 100,000 MW electricity by converting the ocean thermal energy stored in the deep waters off Sabah and Sarawak, where the depth of the seas is 700 meters or more as shown in Figure 2.5-2. Should even 50% of this renewable resource be realised, Malaysia would be in a position to attract capital investments totalling USD500 billion.

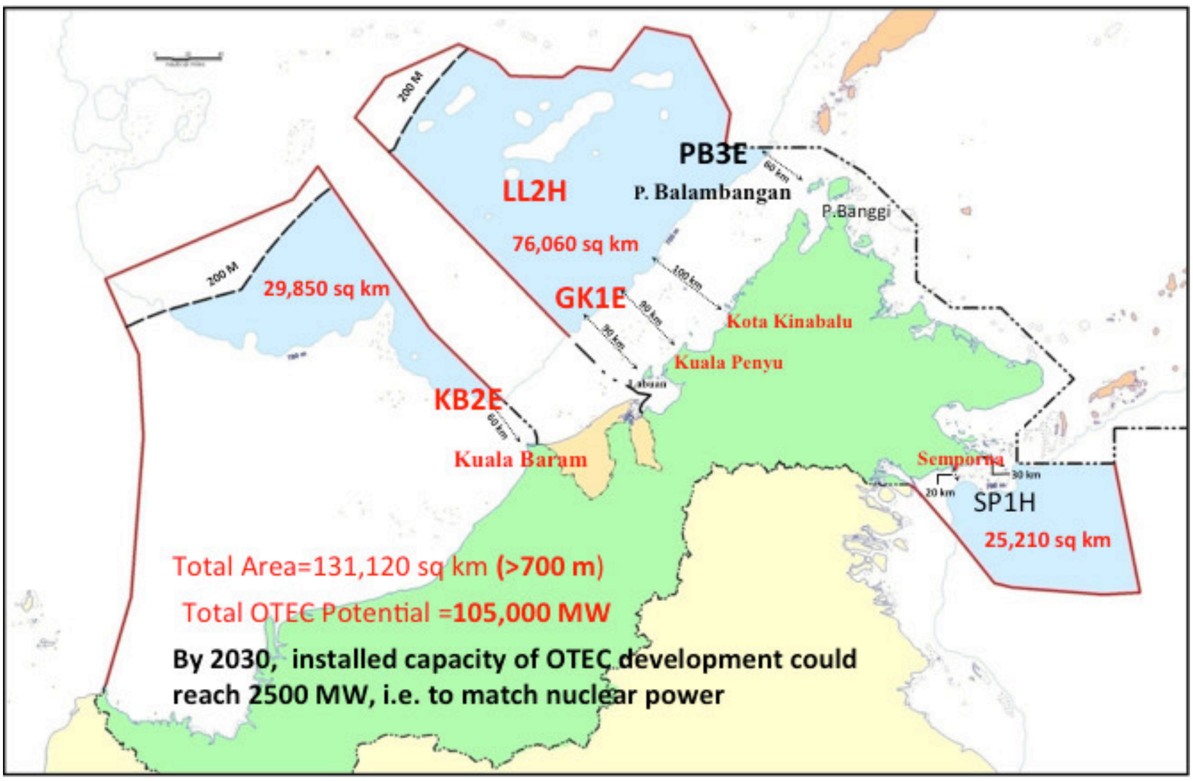


Figure 2.5-2 OTEC potential in Malaysia and the first five OTECT potential sites

In the instances where there are surpluses of electrical power, it would be converted to any energy product equivalent such as hydrogen fuel. Hydrogen fuel is expected to be the most dominant energy carrier in the 21st Century (Ibrahim Dincer 2008).

In addition, there are other spinoffs of the OTEC technology that include the production of temperate foods and produce, high-value marine culture, mineral water, lithium, cosmetics and other beauty products.

2.5.4 Initiatives in Malaysia

Malaysia discovered its potential for ocean thermal energy resource during the Marine Survey of South China in 2006-08. A series of presentations to various agencies and authorities including potential investors has been made since then. On 10 May 2012, Maritime Institute of Malaysia (MIMA) convened the InterAgency and Stakeholders Consultation on OTEC in Putrajaya. On 16 May 2012, the Chairman of Ocean Thermal Energy Corporation of USA paid a courtesy call to YAB Prime Minister of Malaysia and expressed his interest to invest in OTEC in Malaysia. On 3 January 2013, University of Technology Malaysia established its Ocean Thermal Energy Centre. On 18 November 2014, the first Special Purpose Vehicle (SPV) for OTEC in Malaysia, namely, Deep Sea Thermal Solutions Sdn Bhd, was incorporated by PASDEC Holdings Berhad. As of this date, there are at least four other companies that have registered: UTM OTEC Sdn Bhd, UTM OTEC Solutions Sdn Bhd, Sustainable Ocean Thermal Energy Resources Sdn Bhd, and NMIT OTEC Sdn Bhd.

The first likely use of OTEC in Malaysia would be to supply power to the oil & gas production off the deep waters of Sabah. Under the 11th Malaysia Plan (2016-2020), UTM is bidding for an allocation of up to RM350 million to build the first taxpayer-funded 10 MW OTEC plant off Pulau Layang-Layang, largely for security and for the sake of maintaining national sovereignty within Malaysia's national maritime jurisdictions.

2.6 Solar Photovoltaic

Solar photovoltaic (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 standalone 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.

2.6.1 State of the Art

A solar photovoltaic (PV) cell is made of semiconductor materials. When exposed to light, the valence electrons of the semiconductor are excited and freed, producing an 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 an expected lifetime of at least 20 to 30 years. They are also very modular, and thus can be adapted for many locations and applications.

Crystalline Silicon PV

Crystalline silicon solar cells can be divided into two types, namely mono-crystalline and poly-crystalline 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 re-crystallised 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.

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 with glass, metal or plastic. The thickness of such a layer varies from a few nanometers to tens of micrometers. 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%–13%).

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. Thinfilms of organic semiconductor made from polymer and polyethylene are still in the early stages of development. Organic solar cells are potentially the least expensive solar cell, however, its efficiency is currently very low at less than 3%.

Next Generation High-performance Graphene-based Solar Cells

Due to its many interesting properties, graphene and its derivatives offer a promising candidate material for producing the next generation of high-performance solar cells. Many studies indicate that the morphological, electrical, optical and mechanical properties of carbon nanomaterials 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 2.6-1) 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 2.6-1 summarises some research studies focusing on graphene-based solar PV cells.

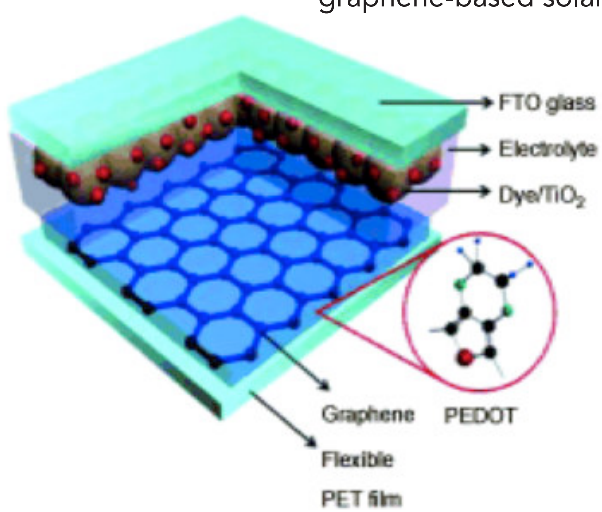


Figure 2.6-1 A dye-sensitised solar cell fabricated with graphene-oxide
(Source: Y.L. Kun Seok Lee)

Table 2.6-1 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

2.6.2 Applications 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 a 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 marked by heavy rainfall. The period of the southwest monsoon is a drier period for Peninsula Malaysia since it is sheltered by the landmass of Sumatra. In general, Sabah and Sarawak receive a greater amount of rainfall than the Peninsula. Hence, heavy rainfall, consistent high temperature, and relative humidity characterise the Malaysian climate.

The mapping of solar radiation can give the best preliminary impression of solar radiation intensity for the different areas in Malaysia. The yearly average daily solar radiation map shows no significant difference in solar radiation intensity between 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 the northern region of

Peninsular Malaysia and southern region of East Malaysia. The southern and northeast region of Peninsular Malaysia as well as most parts of Sabah receive the lowest solar radiation. Studies done by Kamaruzzaman in 1992 and Ayu Azhari in 2009 reveal almost similar results, but show a slight increase in the minimum value, from 3.375 kWh/m^2 in 1992 to 4.21 kWh/m^2 in 2006.

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.

Standalone PV System Applications in Malaysia

In Malaysia, standalone PV systems can be useful in rural electrification. Table 2.6-2 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 2.6-2 Locations of standalone solar PV systems

Locations	Capacity (kWp)
Sabah	616.33
Sarawak	594.13
Kelantan	75.44
Perak	75.97
Pahang	100.13
Johor	127.57
TOTAL	1589.56

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 regions of the Peninsula and the coastal parts of Sabah and Sarawak would yield higher performance. An installation in Kuala Lumpur would yield around 1100 kWh/kWp per year. Other common applications powered by standalone PV systems are street and garden lighting, and parking ticket dispensing machines in some cities like Petaling Jaya.

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, in addition to the diesel generator that generates 6 kW (Figure 2.6-2). 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 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 a performance ratio of 77%. The system cost is RM62.57 per Wp installed and its estimated PV energy generation cost is RM 3.15 per kWh. The maintenance of the system is relatively low except for the diesel generator, which experiences breakdowns and requires battery replacement every five years. The system is estimated to provide a net abatement of 225 tonnes of CO_2 emissions during its lifetime.

Figure 2.6-2 PV-Diesel hybrid system at the Nature and Research Centre, Endau-Rompin National Park

The hybrid PV systems installed at the Middle and Top Stations of Langkawi Cable Car at Gunung Machinchang (Figure 2.6-3) 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 Langkawi Development Authority (LADA) and is operated by Panorama Langkawi Sdn. Bhd.

Figure 2.6-3 Hybrid PV system installed at the Langkawi Cable Car at Gunung Machinchang

Wind turbines can also be incorporated into solar standalone PV systems. The wind turbine-solar PV hybrid system shown in Figure 2.6-4 was installed in April 2010 at the Kuching Waterfront as part of a pilot 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 2.6-4 PV-wind hybrid system at Kuching Waterfront

A diesel-PV hybrid system at the orang asli settlement in Kampung Denai, Rompin, Pahang is used to provide electricity for 15 houses and a school. Kampung Denai is located 35 kilometers from the nearest main road connecting Rompin and Mersing. The total population is 158, involving 22 households. The system consists of a 10 kW PV panel, 10 kW inverter, 150 kWh battery and 18.6kW generator set. The maximum demand was measured at 4195.35 kW.

Grid-connected PV Systems in Malaysia

Grid-connected PV systems are gaining a foothold in the Malaysian energy landscape. Table 2.6-3 shows the total installed capacities of commissioned RE installations under the FIT mechanism; solar PV records the biggest total capacity. Table 2.6-3 indicates that solar PV is a leading and preferred renewable energy resource in Malaysia.

Table 2.6-3 Installed capacity (MW) of commissioned RE installations

Year	Biogas	Biogas (Landfill/ Agri Waste)	Biomass	Biomass (Solid Waste)	Small Hydro	Solar PV	Total
2012	2.00	3.16	43.40	8.90	11.70	31.57	100.73
2013	3.38	3.20	0.00	0.00	0.00	106.97	113.55
2014	1.10	0.00	12.50	0.00	0.00	53.87	67.47
2015	0.00	0.00	0.00	7.00	0.00	0.03	7.03
Cumulative	6.48	6.36	55.90	15.90	11.70	192.44	288.78

(*Source: SEDA Malaysia*)

2.6.3 The Potential of Technologies

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, cost reduction and intangibles such as branding, all of which may well be worth more than the R&D investments made.

Worldwide R&D expenditures on solar PV have doubled over the last decade, rising from USD250 million in 2000 to USD500 million in 2007, with the bulk of it coming from Japan, US and Germany (Figure 2.6-5). It is therefore not a coincidence that these 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.

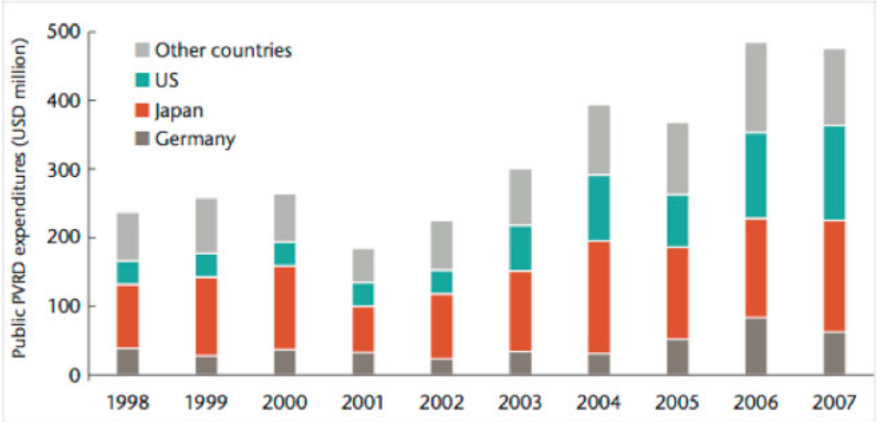


Figure 2.6-5 Worldwide R&D expenditures on solar PV
(Source: IEA, 2013)

Foreign PV manufacturers operating in Malaysia often operate their own in-house R&D, leaving very little room for appropriating added value to Malaysian firms. This is because the foreign MNCs are concerned with 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.

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 to more investment to setting up facilities for glass and polysilicon processing. Notwithstanding 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.

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) in which Malaysian firms already have some operations; the end result is Malaysia would be able to own 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.

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 chain can provide profitable opportunities for local manufacturing companies.

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 exceeds the amount available in the 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 sustainable high volume of domestic PV installations to drive the demands for such services.

2.6.4 Initiatives in Malaysia

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 energy. These policies include the Malaysian Renewable Energy Policy, the National Green Technology Policy, and the Green Technology and Climate Change Council. The Malaysian Renewable Energy Policy (KETTHA, 2008) is aimed at enhancing the utilisation of indigenous renewable energy resources to contribute towards national electricity supply security and sustainable socioeconomic development. The five key strategic thrusts of the policy are:

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 (KeTTHA 2009) 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 renewable energy, of the 10th Malaysia Plan are:

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; and
3. Expansion of local research institutes and institutions of higher learning to expand Research, Development and Innovation 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.

Development of Standards

Standards that are generally applied for PV panels include 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). There are no local testing and standardisation facilities available in Malaysia. However, 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 (VOC), short circuit current (ISC, 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 to 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%.

2.7 Wave Energy & Tidal Current Energy

2.7.1. State of the Art

Wave Energy

With the global attention now being drawn to climate change and the rising level of CO_2, the focus of research once again shifts to generating electricity from renewable sources. The LIMPET shoreline oscillating water column (OWC), installed at Islay, Scotland, in 2000 represents one system that is currently producing power for the National Grid. In September 2008, another commercial wave power system started operating in Northern Portugal. It makes use of the Pelamis power-generating device built by Pelamis Wave (formerly OPD) in Scotland.

Using waves as a source of renewable energy offers significant advantages as follows:

- Sea waves offer the highest energy density among renewable energy sources. Waves are generated by winds, which in turn are generated by solar energy. Solar energy intensity of typically 0.1– 0.3 kW/m^2 horizontal surface is converted to an average power flow intensity of 2–3 kW/m^2 of a vertical plane perpendicular to the direction of wave propagation just below the water surface;
- It is reported that wave power devices can generate power up to 90% of the time, compared to approximately 20–30% for wind and solar power devices.
- There is a large number of concepts for wave energy conversion (WEC); over 1000 wave energy conversion techniques have been patented in Japan, North America, and Europe. Despite this large variation in design, WECs are generally categorised by location and type.

Figure 2.7-1 shows the wave structure produced by wind. Wave energy occurs in the movements of water near the sea surface. Up to 95% of the energy in a wave is located between the water surface and one-quarter of a wavelength below it. The potential energy of a set of waves is proportional to the square of wave height multiplied by squared times wave period (the time between wave crests). Longer period waves have relatively longer wavelengths and move faster. The potential energy is equal to the kinetic energy (that can be expended). Wave power is expressed in kilowatts per meter (at a location such as a shoreline).

The formula below (Eq 2.7-1) shows how wave power can be calculated. Excluding waves created by major storms, the largest waves are about 15 meters high and have a period of about 15 seconds. According to the formula, such waves carry about 1700 kilowatts of potential power across each meter of wavefront. A good wave power location will have an average flux much less than this: perhaps about 50 kw/m.

Formula: Power (in kw/m) = $k H^2 T \sim 0.5 H^2 T$, Eq. (2.7-1)

where k = constant, H = wave height (crest to trough) in meters, and T = wave period (crest to crest) in seconds.

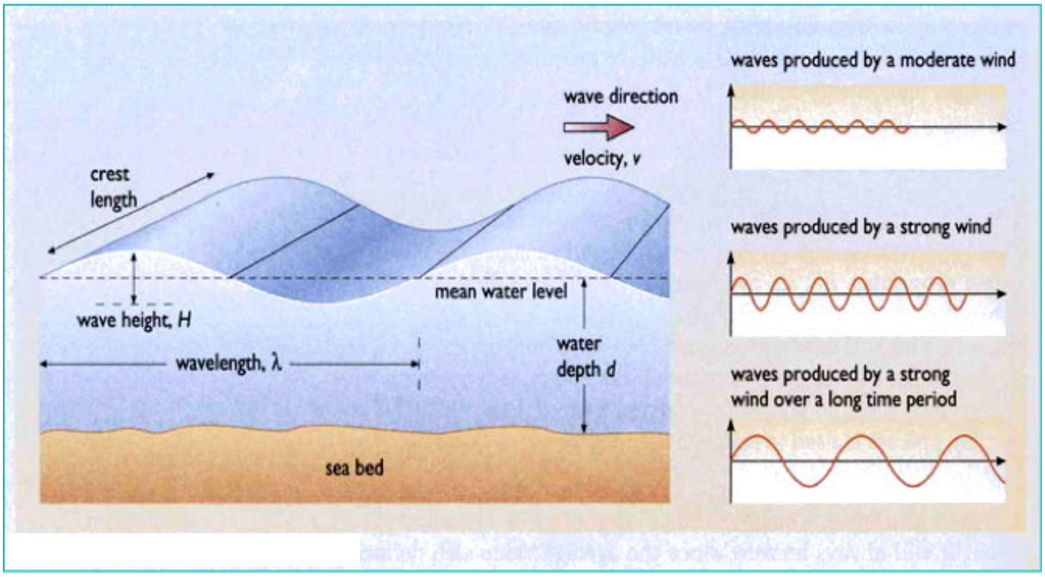


Figure 2.7-1 Wave structure produced by wind

(Source: Boyle, 2004)

Tidal Current Energy

Electricity can be derived by harnessing the kinetic energy in the tidal stream current, namely tidal current energy. Tidal current energy has the distinct advantage of high predictability and regularity, which makes the exploitation of tidal current energy even more attractive. Tidal current turbine (TCT) has developed rapidly in the last decade and the power capacity of a single device has reached a megawatt scale. Many countries started their research on tidal current energy at the end of the last century, such as UK, USA, Canada, Korea, China and Italy, etc. A megawatt scale, Tidal Current Turbine, was designed, tested or planned by some corporations such as Andritz Hydro Hammerfest, Marine Current Turbine (SeagenS, SeagenU, SeagenF), Openhydro, Voith Siemens Hydro, Atlantis resource Corporation, and Alstom.

In principle, the TCT is very much like a submerged windmill but driven by flowing water rather than air. They can be installed in the sea at places with high tidal current velocities, or in a few places with fast enough, continuous ocean currents, to take out energy from these huge volumes of flowing water. The TCT generally can be divided into two categories, namely the horizontal axis tidal current turbine and vertical axis tidal current turbine. TCT captures the kinetic energy of the flowing seawater, so the blades play a vital role, where performance will influence not only the efficiency of the TCT system but also the load characteristics of the rotor and power train. For a tidal barrage, at high tide, a reservoir captures water that the potential energy is released through a turbine. This is similar to a hydroelectric power plant. However, in terms of economical operation, the site needs to have at least 5-7m of the tidal range.

2.7.2 Applications in Malaysia

Although currently, wave energy and tidal current energy in Malaysia have yet to be commercialised, research activities are undergoing at local universities. For instance, the Marine Technology Centre of Universiti Teknologi Malaysia (UTM) is active in marine technology research, including on-site measurement of resource assessment as well as testing in marine laboratory.

2.7.3 The Potential of Technologies

Wave Energy

Figure 2.7-2 shows the potential locations of wave energy in Malaysia, while Figure 2.7-3 shows the potential in terms of average energy flux.

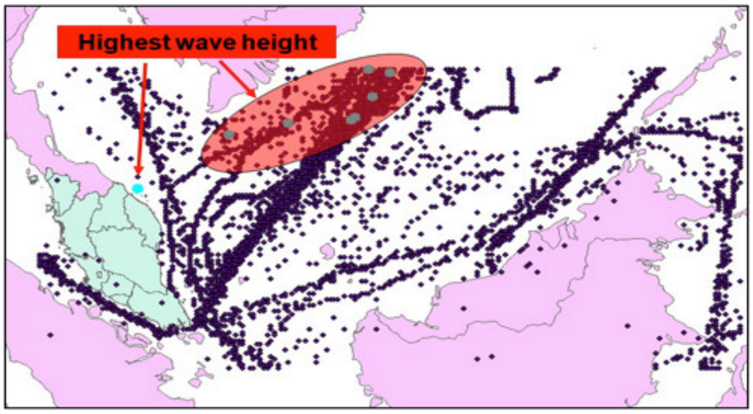


Figure 2.7-2 Potential area of wave energy in Malaysia

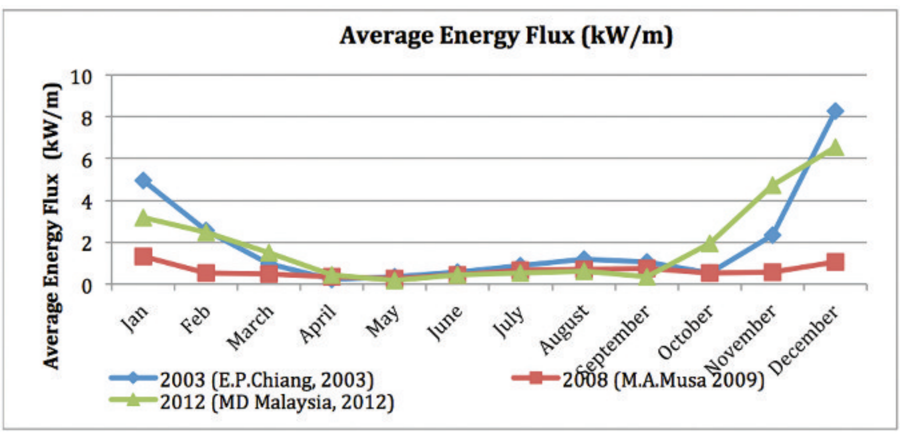


Figure 2.7-3 Monthly average energy flux of wave energy in Malaysia

Tidal Current Energy

Studies have been carried out to investigate the current speed at some of the potential locations (Table 2.7-1). The results show that these locations have low current speed with only 1.1 knots on average.

Table 2.7-1 Current speeds of some potential locations in Malaysia

Location	Maximum speed (knots)	Typical speed (knots)
One Fathom Bank	2.3	0.8 to 1.5
Off Raleigh School	2.2	0.9 to 1.5
Tg Segenting	2.0	0.8 to 1.3
Pulau Tioman (Kampung Teluk Salang)	1.14	0.1 to 0.58

On the other hand, Figure 2.7-4 shows that the tidal ranges at various locations in Malaysia are low, with the majority and maximum tidal ranges of 2m and 4m respectively.

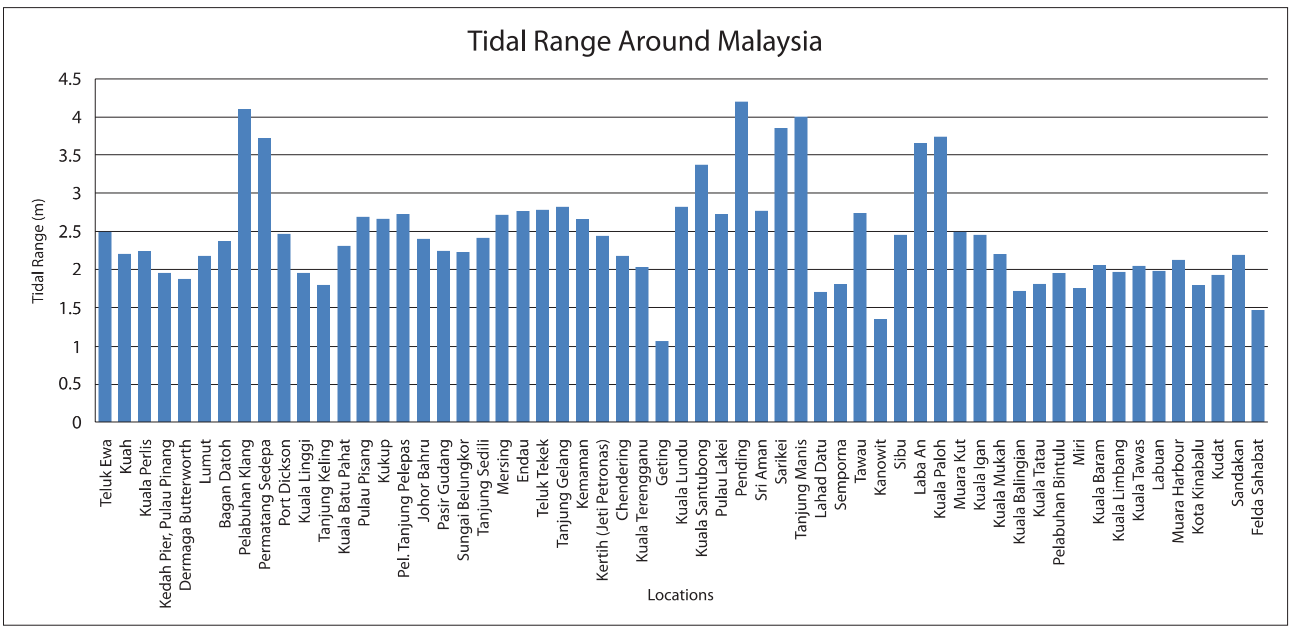


Figure 2.7-4 Tidal ranges at various locations in Malaysia

2.7.4 Initiatives in Malaysia

Almost all of the wave and tidal current technologies, except tidal barrage, are at a conceptual, undergoing R&D, or are in the pre-commercial prototype and demonstration stage. Globally distributed resources and relatively high energy densities can make an important contribution to energy supply and to the mitigation of climate change in the coming decades, if technical challenges can be overcome and costs reduced. Accordingly, a range of initiatives should be employed by the Malaysian government to promote and accelerate the development and deployment of these technologies.

In addition to emission-free electricity generation and potable water production, the Malaysian government should also introduce policy initiatives to promote and accelerate the uptake of marine energy. Some of the policies and initiatives to promote such technologies can be categorised into six areas, namely capacity or generation targets; capital grants and financial incentives, including prizes; market incentives; industry development; research and testing facilities and infrastructure; and permitting/space/resource allocation regimes, standards and protocols.

2.8 Wind Energy

2.8.1 State of the Art

In Malaysia, most of the areas in the mainland experience low wind speed (free stream wind speed $v_\infty < 4$ m/s in more than 90% of the total wind hours) (Chong et al., 2012). Wind power is known to be proportional to the cubic power of the wind velocity approaching wind turbines (Abe et al., 2005). This means that any slight increase in on-coming wind speed can lead to a substantial increase in power output (Ohya et al., 2008). Based on this principle, Chong et al. (2013) designed an innovative omni-direction-guide-vane (ODGV) (Figure 2.8-1), which encloses a vertical axis wind turbine to increase its output power.

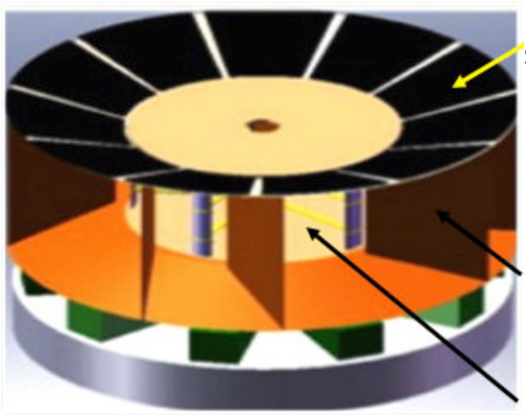


Figure 2.8-1 Omni-Direction Guide Vane (ODGV)

(Source: Chong, 2013a)

The omni-direction-guide-vane (ODGV) (Figure 2.8-1) is an innovative device designed to concentrate on oncoming wind and improve the performance of wind turbines by directing the oncoming wind stream to an optimum flow angle. It increases the wind speed by 1.5 times (Chong et al. 2013). Due to the challenges of surrounding obstacles in urban areas, wind turbines are mounted on top of a high-rise building, as building integrated wind turbines. Also, an innovative idea for harnessing exhaust air from cooling towers was developed by Chong et al. (2013). The recovery wind turbine generator utilises the advantages of discharged air, which is strong, consistent and predictable, and harnesses it for electricity generation (Chong et al. 2013).

2.8.2 Applications in Malaysia

The availability of wind energy in Malaysia has allowed the application of wind energy in Malaysia feasible. Currently, a horizontal axis wind turbine is installed in front of Electrical Energy and Industrial Electronics System (EEIES) Research Cluster, in Perlis. This small horizontal axis wind turbine manages to generate energy to charge a 600 Ah battery system in the research lab. Its maximum output voltage is 40 V dc in a wind speed of 5.54m/s (UniMAP). Tenaga Nasional Berhad (TNB) installed two units of wind turbines with 100 kW capacity each in Pulau Perhentian as shown in Figure 2.8-2.

Figure 2.8-2 Wind and Solar hybrid power station at Pulau Perhentian

The Ministry of Rural and Regional Development installed eight units of small wind turbines rated between 5-100 kW for the rural communities in Sabah and Sarawak (Rajkumar et al., 2011). Wind-solar hybrid street lamp posts with ODGV were also installed by Assoc. Prof. Dr Chong Wen Tong and his research team at the University of Malaya, Mid Valley and Ulu Gombak, Selangor. The ODGV is a wind concentrator that concentrates the wind speed to the optimum angle when hitting the wind turbine; it also increases the oncoming wind speed by 1.5 times thereby improving the performance of the vertical axis wind turbine (Figure 2.8-3).

Figure 2.8-3 Installed wind-solar hybrid street lamp post with (ODGV) at Mid Valley, Kuala Lumpur

Building integrated wind turbine is a technology that presents a high potential for the integration of wind turbine within the built environment. In Malaysia, wind turbines that are built and integrated on high-rise buildings as hybrid systems have good potential as reported by Chong et al. (2011) (Figure 2.8-4).

Figure 2.8-4 3-in-1 building integrated wind-solar hybrid energy system with rain water collection features retrofitted on top of some the buildings in Kuala Lumpur Malaysia
(Source: Chong et al., 2011)

Another application of wind turbines that can be used in Malaysia is the exhaust air energy recovery system. The exhaust air energy recovery wind turbine generator (shown in Figure 2.8-5) is an on-site clean energy generator that utilises the advantages of discharged air, which is strong, consistent, and predictable. Two vertical axis wind turbines (VAWTs) in cross-wind orientation which are integrated with an enclosure are installed above a cooling tower to harness the discharged wind for electricity generation (Chong et al., 2013).

Figure 2.8-5 Artist's impression of the designed exhaust air energy recovery system on top of a high rise buildings
(Source: Chong, 2013b)

2.8.3 The Potential of Technologies

Wind energy is one of the potential sources of renewable energy in Malaysia that can be utilised to achieve 5% of renewable energy in the Malaysia energy mix. Wind energy is crucial for electricity companies as it is a clean, free and inexhaustible energy resource. Malaysia has good prospects in wind energy development as many institutions of higher learning and research institutions have conducted research on the potential of wind energy in Malaysia.

The Solar Energy Research Institute (SERI) from Universiti Kebangsaan Malaysia (UKM) analysed wind data from 1982 to 1991 from 10 different stations distributed all over Malaysia with six from Peninsular and four from Sabah and Sarawak. Their results indicate that the stations in Mersing and Kuala Terengganu have the highest wind power potential in Malaysia (Azami et al. 2009; Sopian et al. 1995). Currently, Sustainable Energy Development Agency (SEDA) has started working on the wind energy map for Malaysia.

Small wind turbines can be used to provide electricity on the relatively undeveloped east coast of Peninsular Malaysia and offshore islands (Sopian et al. 1995). A study conducted by UKM in 2005 has shown that the use of 150 kW turbine on the Terumbu Layang-Layang island has met with a good degree of success (Sahfie et al. 2011). A regional assessment of wind power in Malaysia as presented in a letter to the editor indicates that several regions such as northeast, northwest and southeast region of Peninsular Malaysia are found to have potential for generating wind energy (Masseran et al. 2012).

Albani et al. (2013) assessed the wind potential in Kudat and Labuan. Both studies reveal that these places have the potential for developing small-scale wind energy systems for electricity generation in East Malaysia. A further study by Sopian and Khattib (Sopian et al., 2013) revealed that Kudat has the highest potential for wind energy followed by Mersing, given the monthly mean wind speed of more than 2m/s throughout the year (Figure 2.8-6). Recently, wind speed data at offshore Terengganu showed that the wind potential here is good enough (capacity factor ~ 25%) for building small offshore wind farms.

The potential of wind energy in Malaysia cannot be underestimated, although most of the areas in the mainland experience low wind speeds (free-stream wind speed v_∞<4m/s) for more than 90% of the total wind hours. Harnessing wind energy is feasible only in some strategic parts in Malaysia. Strong winds in the east coast of Peninsular Malaysia and some parts of Sabah and Sarawak indicate some feasibility. The numerical weather prediction (NWP) models by Nor et al. (2014) showed that there is good potential for wind energy in Malaysia. Kuala Terengganu and Mersing, located in the east coast of Peninsular Malaysia and Kudat in Sabah have the greatest wind power potential in Malaysia.

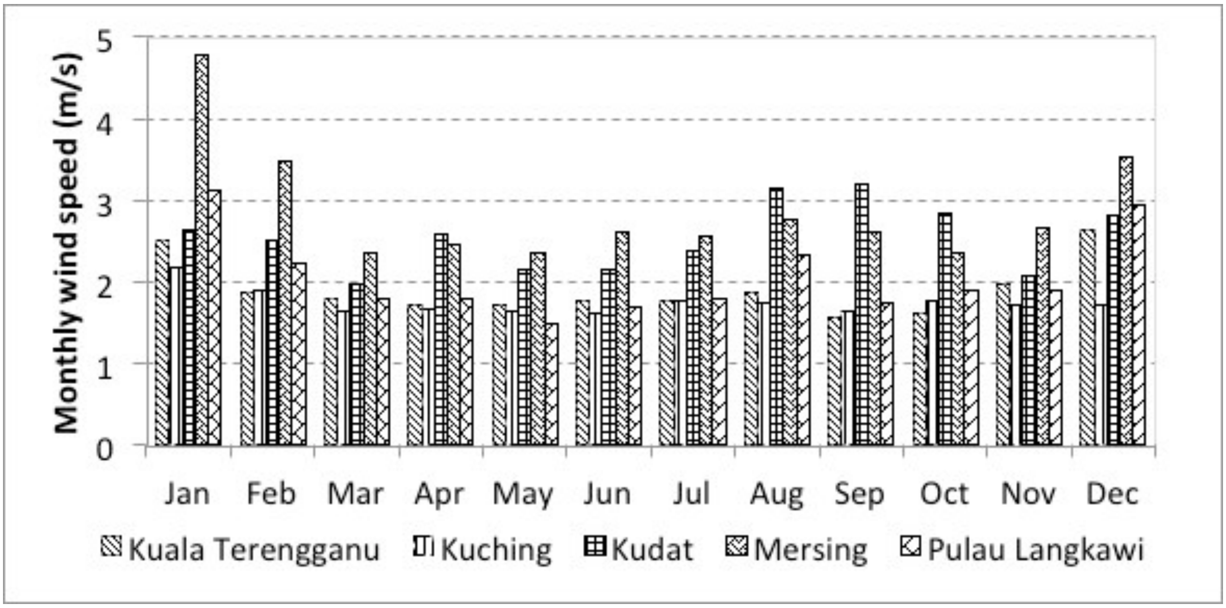


Figure 2.8-6 Monthly mean wind speed in some locations in Malaysia
(Source: Sopian & Khatib, 2013)

Wind Conditions and Mapping of Wind Speed in Malaysia

A wind map that shows wind resource potential based on wind power density can help estimate wind energy resources for a given country, or region and its territories by indicating or identifying areas with high wind resources. The wind map is very important to ensure a successful wind energy project. The wind map can be used to establish a meteorological basis for the assessment of wind energy resource; the main objective is providing suitable data to help evaluate the potential of wind energy at a particular site by determining the potential electricity output generated from the installed wind turbine. In addition, the wind map provides data and guidelines for the meteorology aspects of the detailed sitting of large and small wind turbines.

Nurulkamal et al. (2012) presented a study on the spatial analysis of wind potential in East Malaysia (Figure 2.8-7). Using the Kriging (or Gaussian) and inverse distance weighing method, they described the spatial distribution of wind speed. Figure 2.8-8 shows the spatial estimation of theoretical mean wind speeds in Sabah and Sarawak. The output of their research indicates that most regions in Sabah and Sarawak experience wind speeds in the range of 4.3 to 6.3 km/hour. For East Malaysia, they concluded that the southern region of Sarawak state has the highest theoretical mean wind speed compared to the other regions, thus having the highest potential of producing wind energy.

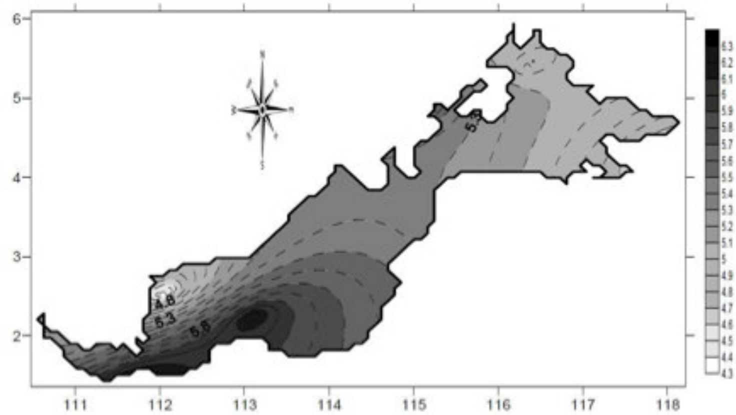


Figure 2.8-7 Map of wind speeds in East Malaysia
(Source: Nurulkamal et al., 2012)

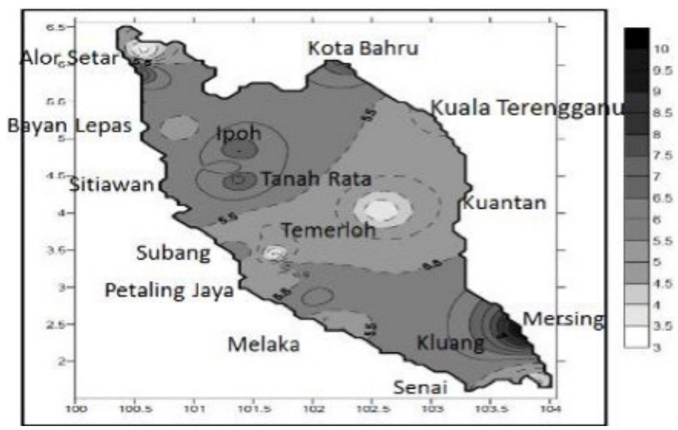


Figure 2.8-8 Map of mean wind speeds in Peninsular Malaysia

Potential Areas for Installing Wind Energy Technologies in Malaysia

In Malaysia, the potential areas for the installation of wind energy technologies are as follows:

- Remote areas which are far from the national grid. These include rural areas, resorts and habitable islands (Figure 2.8-9), offshore platforms (Figure 2.8-10), farms, beaches and telecommunications towers, mountains, hillsides and agricultural lands. In addition, Figure 2.8-11 and Table 2.8-1 show the potential locations for wind energy in Malaysia; and
- In urban areas, the potential applications of wind turbines include building integrated wind turbines, street lamp posts, cooling towers with exhaust air systems and others.

Figure 2.8-9 Island: Pulau Banggi

Figure 2.8-10 Typical wellhead platform in offshore Malaysia (Courtesy: Technip)

(a)		(b)	
1	Pulau Banggi (Sabah)	11	Sibu Island (Johor)
2	Labuan Island	12	Pulau Kuraman (Labuan)
3	Penang Island	13	Pangkor Island (Perak)
4	Pulau Perhentian (Terengganu)	14	Pulau Besar (Johor)
5	Langkawi Island	15	Malawali Island (Sabah)
6	Terumbu Layang-Layang	16	Jambongan Island (Sabah)
7	Redang Island (Terengganu)	17	Pulau Tenggol (Terengganu)
8	Pulau Besar (Malaka)	18	Pulau Mabul (Sabah)
9	Pulau Lang Tengah(Terengganu)	19	Balambangan Island (Sabah)
10	Tioman Island (Pahang)	20	Ketam Island (Selangor)

Figure 2.8-11. Islands in (a) Peninsular and (b) East Malaysia with potential for wind energy

2.8.4 Initiatives in Malaysia

Initiatives on sustainable development are being aggressively pursued throughout the world. The Malaysian government has developed key policies and strategies over the past 30 years to achieve the nation's policy objectives, which are designed to mitigate issues of energy security, efficiency and environmental impact to meet the rising energy demand. Malaysia's current focus is on developing effective policies on renewable energy (RE) in order to reduce dependency on fossil fuel and contribute towards mitigating the effects of climate change (Hashim et al. 2011).

Malaysia's economic development will still be an important strategic task over the next 20 years. Wind energy is one of the renewable energy sources most likely to be developed commercially on a large scale and hence could support Malaysia's economic development due to its cost effectiveness and low environmental impact. The first step in initiating any wind energy project is to understand the available wind energy resource in the area of interest.

It is the most crucial step towards the planning of any wind energy projects; therefore, a wind energy map for Malaysia is very much a requirement if wind energy is be developed as a potential renewable energy source in the country. Furthermore, the utilisation of wind power is not limited by resources and environmental constraints. Wind can be sustainably developed on a large scale, and its target and strategies should be established on a long-term basis.

Chapter 3

Carbon Free Energy Roadmap

3.1 Methodology Approach

There were three stages in the roadmap development process, which involved meetings, workshops and email communications (Figure 3.1-1).

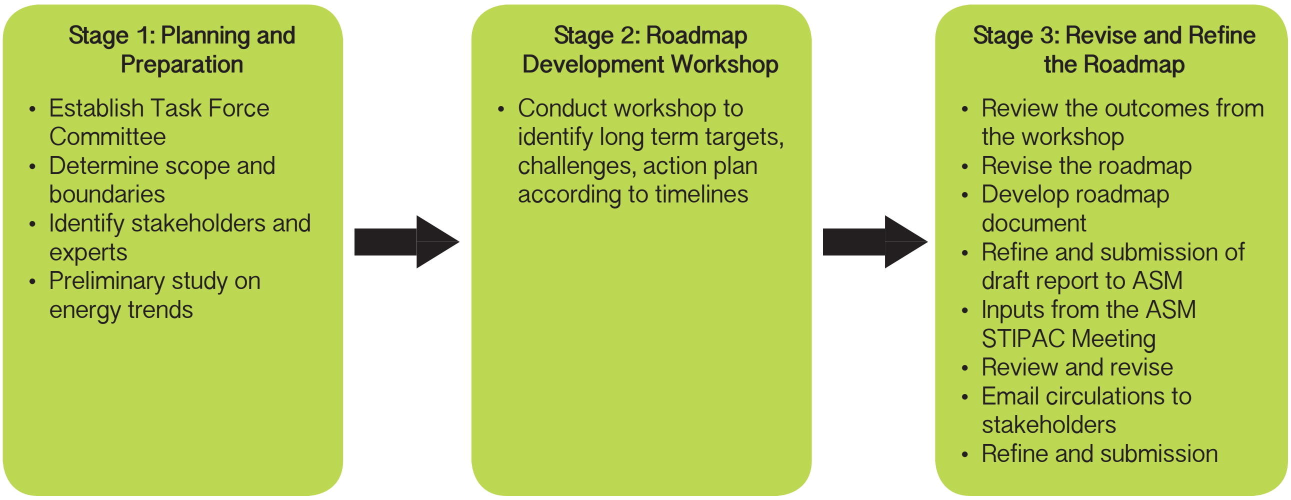


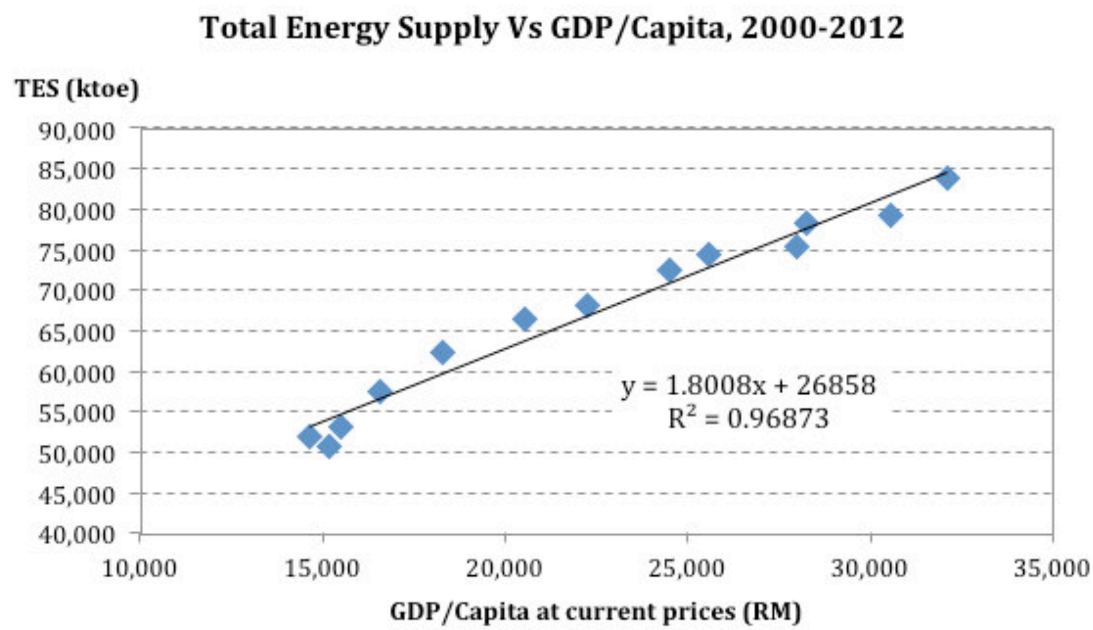
Figure 3.1-1 Roadmap development process

3.1.1 Stage 1: Planning and preparation

A Task Force Committee on carbon-free energy was established and the list of the members is presented in Chapter "Carbon-Free Energy Task Force Committee & Contributors". Several meetings were conducted to determine the scope and boundaries of the roadmap. Stakeholders and experts in the field of energy were identified and invited to participate in the roadmap development workshop. Prior to the workshop, a preliminary study on energy trends was carried out to establish baseline data, analyse historical trends and suggest future trends and targets.

From historical statistics (Energy Commission 2012), GDP per capita was identified as the main driver for both total energy supply and electricity consumption. The correlations are shown in Figure 3.1-2. These correlations are used to project the total energy supply and electricity consumption for scenarios of "business as usual". On the other hand, the projections of GDP and capita growth rates were cited from the projections of IEA Southeast Asia Energy Outlook Report (IEA, 2013). The projected figures from 2012 to 2050 are shown in Table 3.1-1.

a)



b)

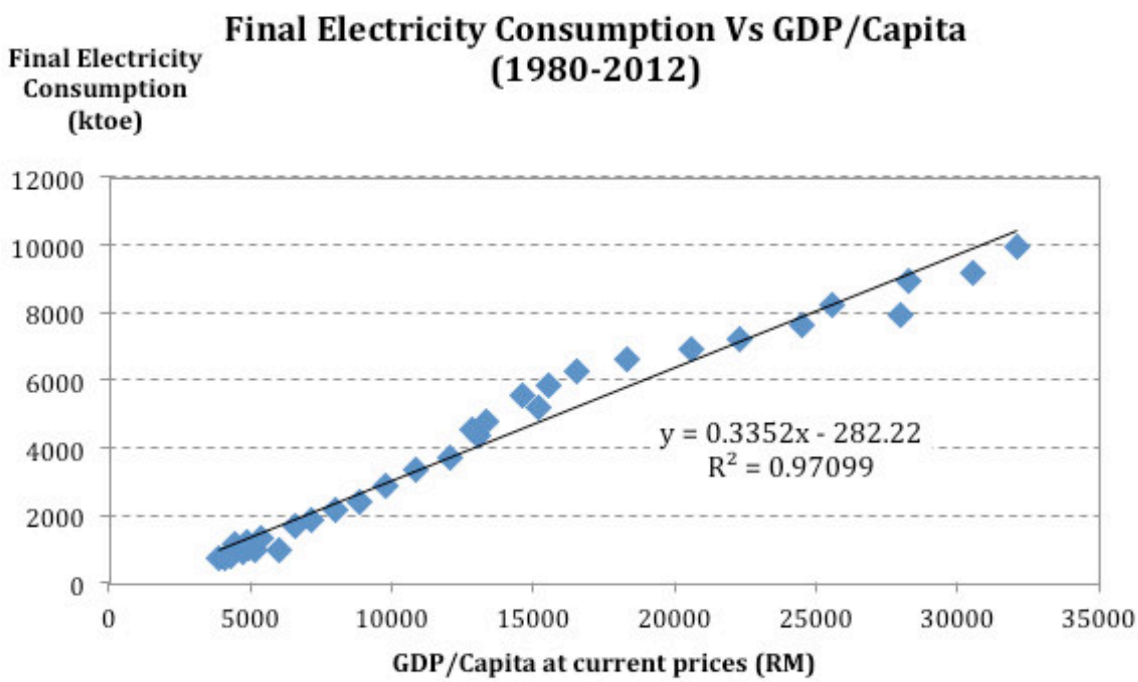


Figure 3.1-2 Correlations between (a) Total energy supply (TES); (b) Total final electricity consumption and GDP/capita

Table 3.1-1. Amounts of total energy supply and final electricity consumption form 2011 to 2050

Year	GDP/Capita[a] (RM, current prices)	TES[b] (ktoe)	Final Electricity Consumption[c] (ktoe)
2011[d]	30536	79289	9235
2012 [d]	32084	83937	10011
2015	34855	89625	11401
2020	40016	98919	13131
2025	45941	109588	15117
2030	52743	121838	17397
2035	60552	135900	20015
2040	69518	152046	23020
2045	79811	170581	26470
2050	91628	191861	30431
CAAGR (%)	2.80	2.20	3.28

[a] Values for years 2015 to 2050 were calculated based on 2.8% of CAGR, adopted from IEA 2013
[b] Values for years 2015 to 2050 were calculated based on:
TES= 1.8008*(GDP/capita) + 26858, R^2= 0.96873
[c] Values for years 2015 to 2050 were calculated based on:
Final electricity consumption= 0.3352*(GDP/capita) - 282.22, R^2= 0.97099
[d] Data for years 2011 and 2012 were obtained from the NEB 2012

3.1.2 Stage 2: Roadmap development workshop

The Carbon Free Energy Roadmap Workshop was held in Melaka, from 20 to 22 January 2015.

Backcasting Approach

The roadmap targets were developed by using the backcasting approach. This approach stipulates the "end-state" rather than deriving it. A backcasting approach is able to highlight the policy direction in order to achieve future targets and objectives. In contrast, the common approach that has been used to develop the policy targets – "forecasting", tends to extend current trends out into the future to see where they might arrive. Therefore, the proposed targets in this study are different from the existing energy targets of KeTTHA.

This approach was introduced to the participants of the workshop, who are stakeholders of the energy sector. The end-state and targets to be achieved in 2050 were set and actions that need to be taken from current year to 2050 were discussed in separate groups.

The participants were divided into seven groups and led by a group leader as follows:

1) Bioenery; Leader: Prof Dr Mohd Ali Hassan
2) Geothermal; Leader: Prof Dr Sanudin Tahir
3) Hydropower; Leader: Prof Dr Abdul Halim Shamsuddin
4) OTEC; Leader: Prof Dato' Dr Abu Bakar Jaafar
5) Solar PV; Leader: Prof Dr Norani Muti Mohamed[2]
6) Tidal and wave; Leader: Prof Mohd Zamri Bin Ibrahim
7) Wind energy; Leader: Dr Chong Wen Tong

The initial definition of "energy" of the roadmap was referred to the total energy supply and nuclear energy was excluded. In each group, the participants discussed targets, challenges and action plan for each respective carbon-free energy source. The projections of energy trends (Table 3.1-2) were proposed to the participants. However, these targets were then readjusted and the values were revised as shown in Table 3.1-3, while the targets in percentages from 2012 to 2050 are illustrated in Figure 3.1-3.

These targets were set based on the total energy supply, but after brainstorming sessions over a period of 1.5 days, the task force and the workshop participants had to accede that the targets set were too challenging to achieve. For instance, in order to meet the demand from carbon-free energy sources, the supply from the solar PV would need to be increased from less than 1% (less than 0.5 ktoe) to 44.6% (85.6 ktoe) in 2050, a drastic rise in 35 years' time from the present year of 2015.

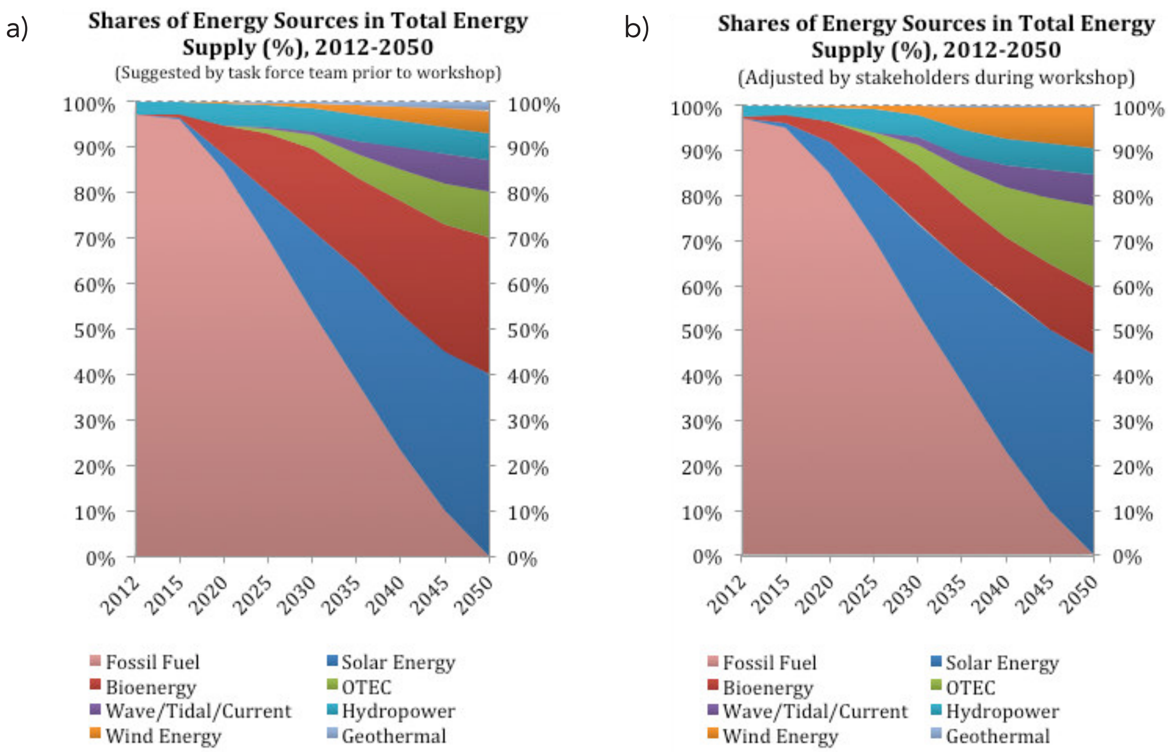


Figure 3.1-3 Shares of energy sources in total energy supply from 2012-2050, which were (a) suggested prior to workshop and (b) readjusted during the workshop

[2] Led the solar PV group discussion during the workshop, but the solar PV group leader of the task force was Prof Dr Kamaruzzaman Sopian.

Table 3.1-2. Suggested targets by the task force team prior to the roadmap development workshop

	Solar		Total Bioenergy		OTEC		Wave/ Tidal/ Current		Hydro power		Wind		Geothermal		Fossil		Total	Total
	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	(%)	(ktoe)
2012	0.0	0	0.4	302	0.0	0	0.0	0	2.6	2,149	0.0	0	0.0	0	97.1	81,486	100	83,937
2015	0.5	448	1.0	896	0.0	0	0.0	0	2.6	2,330	0.0	0	0.0	0	95.9	85,951	100	89,625
2020	3.5	3,462	6.0	5,935	0.2	198	0.1	99	5.0	4,946	0.1	99	0.1	99	85.0	84,081	100	98,919
2025	10.0	10,959	13.0	14,246	1.0	1,096	0.4	438	5.0	5,479	0.4	438	0.2	219	70.0	76,712	100	109,588
2030	18.0	21,931	18.0	21,931	3.0	3,655	1.0	1,218	5.0	6,092	1.0	1,218	0.5	609	53.5	65,183	100	121,838
2035	25.0	33,975	20.0	27,180	5.0	6,795	3.0	4,077	6.0	8,154	2.0	2,718	0.7	951	38.3	52,050	100	135,900
2040	30.0	45,614	25.0	38,012	7.0	10,643	5.0	7,602	6.0	9,123	3.0	4,561	1.0	1,520	23.0	34,971	100	152,046
2045	35.0	59,703	28.0	47,763	9.0	15,352	6.5	11,088	6.0	10,235	4.0	6,823	1.5	2,559	10.0	17,058	100	170,581
2050	40.0	76,744	30.0	57,558	10.0	19,186	7.0	13,430.3	6.0	11,512	5.0	9,593	2.0	3,837	0.0	0	100	191,861

Table 3.1-3. Readjusted targets by the stakeholders during the roadmap development workshop

	Solar		Total Bioenergy		OTEC		Wave/ Tidal/ Current		Hydro power		Wind		Geothermal		Fossil		Total	Total
	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	%	ktoe	(%)	(ktoe)
2012	0.0	0	0.4	302	0.0	0	0.0	0	2.6	2,149	0.0	0	0.0	0	97.1	81,486	100	83,937
2015	1.0	896	2.0	1,793	0.0	0	0.0	0	2.0	1,793	0.0	0	0.0	0	95.0	85,144	100	89,625
2020	6.8	6,677	4.5	4,451	0.2	198	0.1	99	3.0	2,968	0.4	396	0.1	49	85.0	84,081	100	98,919
2025	12.8	14,049	10.0	10,959	1.0	1,096	0.4	438	5.0	5,479	0.7	767	0.1	88	70.0	76,712	100	109,588
2030	20.0	24,392	13.0	15,839	4.4	5,337	2.0	2,437	5.0	6,092	2.0	2,437	0.1	122	53.5	65,183	100	121,838
2035	26.7	36,340	13.0	17,667	7.8	10,546	3.0	4,077	6.0	8,154	5.0	6,795	0.2	272	38.3	52,050	100	135,900
2040	34.6	52,547	13.0	19,766	11.1	16,938	5.0	7,602	6.0	9,123	7.0	10,643	0.3	456	23.0	34,971	100	152,046
2045	40.0	68,232	14.6	24,871	14.5	24,768	6.5	11,088	6.0	10,235	8.0	13,646	0.4	682	10.0	17,058	100	170,581
2050	44.6	85,570	15.0	28,779	17.9	34,343	7.0	13,430	6.0	11,512	9.0	17,267	0.5	959	0.0	0	100	191,861

3.1.3 Stage 3: Revising and refining the roadmap

In order to develop an achievable carbon-free energy vision, members of the task force team were asked to redefine "carbon-free energy" from "total energy supply" to "electricity generation".

Therefore, the projection exercises were repeated for electricity generation. Similar to the earlier projections, GDP/capita was used as the driver in the correlation analysis method to project the electricity generation. In addition, an energy efficiency target was included, whereby 10% of electricity saving[3] from 2015 is to be achieved by 2050, equivalent to 11,003 ktoe of a cumulative saving (Figure 3.1-4). As a result, 2.8% of CAAGR that was projected by IEA (2013) was reduced to about 2.5% of CAGR of electricity generation. Also, nuclear energy and fuel cell were included as additional sources of carbon-free energy.

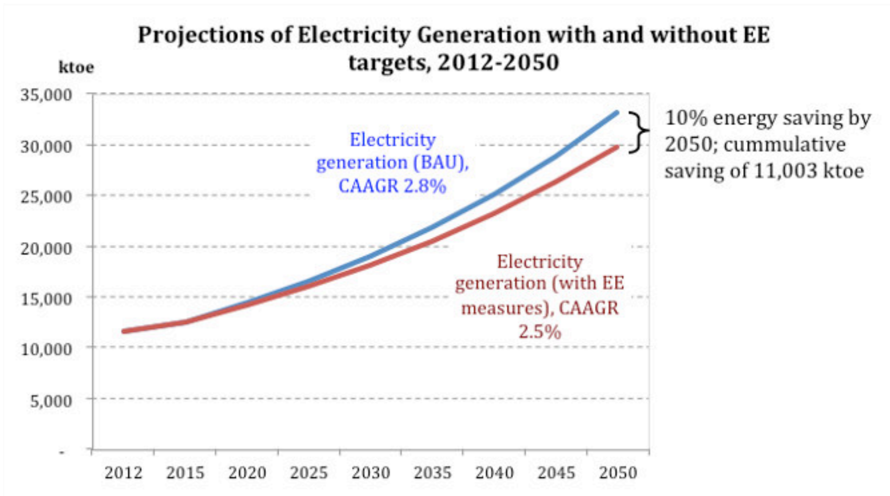


Figure 3.1-4 Projection of electricity generation with 10% of energy saving by 2050

Refined with Comments from the STIPAC Meeting on the First Draft Report

The present report is the second draft report and was prepared taking into account the comments from the committee of STIPAC Meeting on 28th May 2015. Details on the comments and responses from the Task Force team are described in Appendix A.

3.2 Introduction of Hydrogen Economy[4]

Most of the renewable energy resources are uncertain due to the climate and weather conditions. This will be a critical issue especially when renewable energy has become dominant in the energy supply. Therefore, energy storage plays a crucial role to store excess energy that can be accessed when renewable energy resources are unavailable or when supply mismatches demand. Hydrogen energy storage can be one of the solutions in this regard.

Therefore, apart from the installed capacities for direct electricity generation, part of the total installed capacities of some carbon-free energy sources would be used to generate hydrogen. The generated hydrogen will then be used in fuel cell applications to generate electricity. And hence, this task force acknowledges fuel cell as a carbon-free energy source for electricity generation.

[3] The target is set based on assumption. Discussion on strategies in achieving this target is beyond the scope of this report.
[4] The mechanism of hydrogen economy is beyond the discussion of this report and will be discussed separately in detail in the Fuel Cell Task Force.

3.3 Projections of Future Energy Mix Patterns

The task force team agreed to propose two different scenarios of carbon-free energy roadmap. Scenario-1 is to achieve a carbon-free energy mix in electricity generation by 2050; and Scenario-2 is to achieve net zero carbon emissions in electricity generation by 2050. These two scenarios will be further discussed in the following sections.

Table 3.3-1 gives the capacity factors according to fuel types, which were used to calculate the installed capacity that is required to meet the electricity demand for these two scenarios.

Table 3.3-1 Capacity factors of different energy sources in electricity generation

	Capacity Factor									
	Bioenergy	**Fuel Cell**	**Geothermal**	**Solar PV**	**Hydro power**	**Nuclear**	**OTEC**	**Wave/ Tidal/ Current**	**Wind Energy**	**Fossil Fuel**
2012	0.37	0	0	0.14	0.34	0	0	0	0	0.70
2015	0.37	0	0	0.14	0.34	0	0	0	0	0.70
2020	0.40	0.9	0.75	0.15	0.34	0	0.90	0.25	0.25	0.70
2025	0.50	0.9	0.75	0.15	0.34	0.70	0.90	0.25	0.25	0.70
2030	0.60	0.9	0.75	0.15	0.34	0.70	0.90	0.25	0.25	0.70
2035	0.70	0.9	0.80	0.16	0.34	0.70	0.90	0.30	0.25	0.70
2040	0.70	0.9	0.80	0.16	0.34	0.70	0.90	0.30	0.30	0.70
2045	0.70	0.9	0.80	0.17	0.34	0.70	0.90	0.30	0.30	0.70
2050	0.70	0.9	0.80	0.17	0.34	0.70	0.90	0.30	0.30	0.70

Calculations and assumptions applied to Table 3.3-1 are as follows:

a) Capacity factors of fuel cell, nuclear energy, OTEC, wind energy, geothermal, wave, and tidal current energy are based on estimations.

b) Capacity factors of solar PV, bioenergy, wave, tidal current, wind and geothermal energy are expected to increase gradually when the harnessing capacities of the technologies are improved.

c) Capacity factors for hydropower and fossil fuels in 2012 are based on calculations using equation 3.1:

$$\text{Capacity factor} = \frac{\text{(Total electricity generated in 2012)}}{\text{(Available capacity*24 hours*365 days)}} \quad \text{Eq. (3.1)}$$

whereby data for total electricity generation and available capacity were obtained from NEB 2012 (Energy Commission 2012).

Note: instead of using "installed capacity", "available capacity" was used because it was stated in the NEB 2012 that some of the facilities are aged or broken down.

d) The capacity factor for the hydropower is only about 0.34. This is because large hydropower plants in Malaysia have been used as peaking plants and the remaining capacity has been reserved to comply with a minimum reserve margin of 30% of the total national grid. Nonetheless, this value of capacity factor will be retained till 2050 due to the fact that most of the hydropower plants are large scale and hence the operation capacity needs to be controlled to avoid adverse impact on the environment.

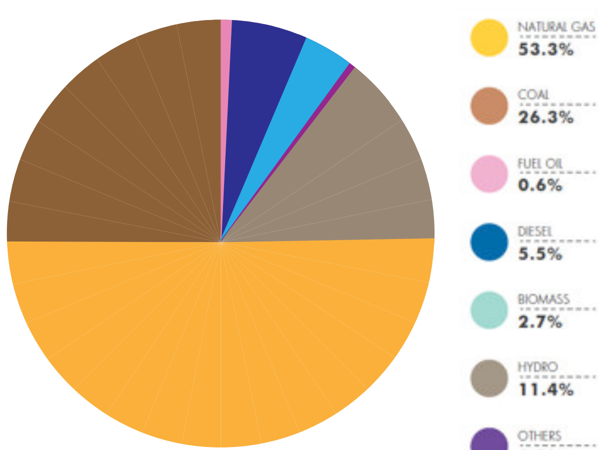
e) The capacity factor for the fossil fuels was calculated based on the total of all types of fossil fuels used in power plants and it was derived from NEB 2012.

f) As data from NEB 2012 on available capacity did not match electricity generation of bioenergy, whereby the generated amount was greater than the amount that would be available, the capacity factor for bioenergy was calculated based on the ratio of energy input to electricity generated.

g) In this study, municipal solid waste (MSW) treated by incineration is taken into account for electricity generation from bioenergy. It is assumed that 1 tonne of MSW will generate a net energy of 0.67 MWh (Rahman 2013), with a capacity factor of 0.7.

3.4 Vision for Carbon Free Energy Future

Figure 3.4-1 shows the energy mix of power generation in 2012. Nearly 86% of the total installed capacity was from the fossil fuels. This indicates that Malaysia is highly dependent on fossil fuels in the electricity sector. Natural gas, the dominant fuel has been continuously depleting and the first import of LNG to Peninsula took place in August 2013. Furthermore, almost all of the coal is also imported. Together, these two fuels account for about 80% of the current energy mix. In terms of sustainability, this energy mix needs to be diversified with more alternative fuels, which are available locally, and not be dependent on fossil only.



Total: 29,143 MW

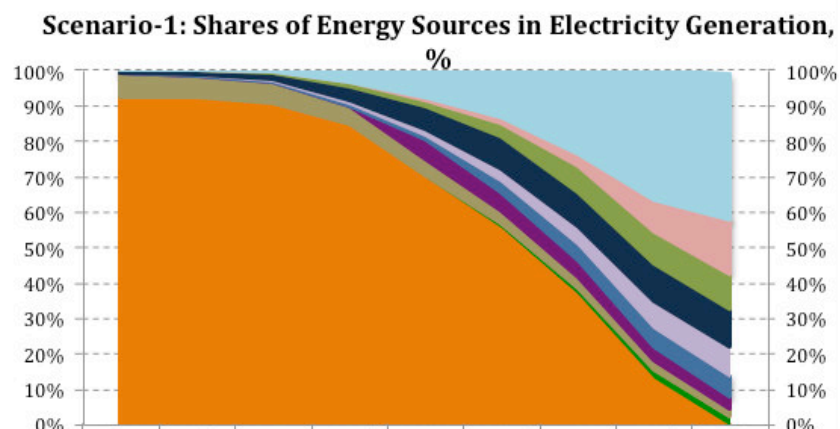
Figure 3.4-1 Fuel shares of Installed capacity in 2012

3.4.1 Scenario-1: Carbon Free Energy Mix in Electricity Generation

In this scenario, there would be no fossil fuels used for electricity generation by 2050.

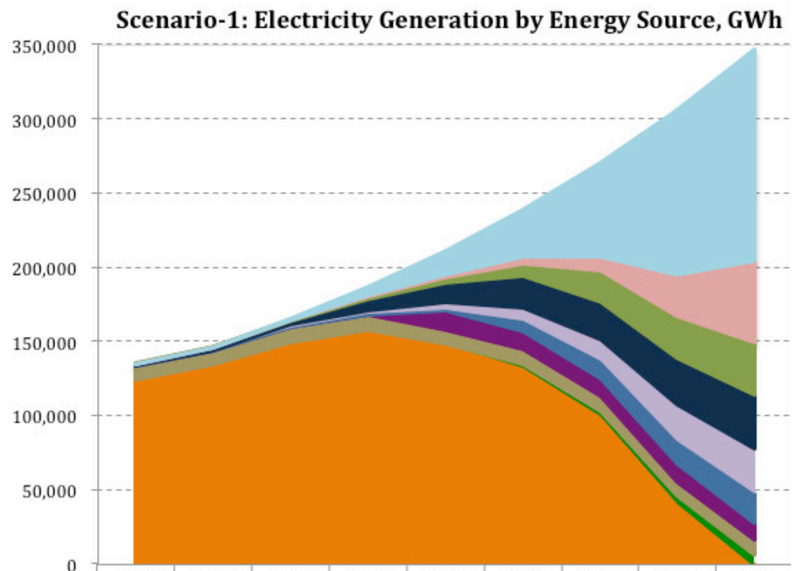
Direct Electricity Generation

The projections show the evolution of energy mix in electricity generation from 2012 to 2050. Fossil fuels used in electricity generation will be gradually reduced and completely phased out by 2050, while other carbon-free energy resources will be used to fill the gap in supply. Electricity generation by energy sources in terms of percentages and GWh are shown in Figures 3.4-2 and 3.4-3, respectively. In 2012, nearly 93% or 125,000 GWh of electricity was generated from fossil fuels. The projected total electricity demand by 2050 will be 345,000 GWh; hence the alternative fuels not only need to replace the present demand (125,000 GWh) but also need to be intensified to meet the future demand. Therefore, the energy mix needs to be diversified in the future to secure supplies.



	2012	2015	2020	2025	2030	2035	2040	2045	2050
OTEC	0.0	0.0	0.1	3.1	7.5	13.2	23.4	36.2	41.1
Fuel Cell	0.0	0.0	0.1	0.2	0.7	1.6	3.3	9.1	15.7
Wind Energy	0.0	0.0	0.3	1.2	2.1	3.7	7.8	9.5	10.7
Bioenergy	0.6	1.0	1.7	3.9	6.3	9.3	9.6	10.0	10.3
Solar PV	0.0	0.3	0.6	1.1	1.9	3.5	5.2	8.1	8.6
Wave/ Tidal/ Current	0.0	0.0	0.3	0.6	0.7	3.0	4.3	5.0	5.8
Nuclear	0.0	0.0	0.0	0.0	5.8	5.1	4.5	4.0	3.4
Hydropower	6.7	6.1	5.8	5.1	4.5	4.0	3.5	3.1	2.8
Geothermal	0.0	0.0	0.3	0.4	0.5	1.1	1.6	2.1	2.5
Fossil Fuel	92.7	92.6	90.8	84.5	70.0	55.5	36.7	13.0	-0.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.2

Figure 3.4-2 Proposed shares of energy sources in electricity generation of Scenario-1 from 2012 to 2050



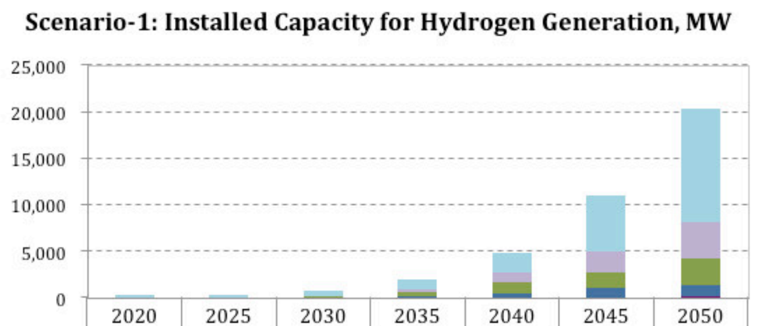
	2012	2015	2020	2025	2030	2035	2040	2045	2050
OTEC	0	0	134	5,696	15,768	31,536	63,072	110,376	141,910
Fuel Cell	0	0	219	352	1,476	3,840	8,878	27,782	54,162
Wind Energy	0	0	547	2,190	4,380	8,760	21,024	28,908	36,792
Bioenergy	809	1,455	2,802	7,348	13,350	22,075	25,895	30,645	35,730
Solar PV	7	437	1,053	1,974	3,948	8,420	14,033	24,592	29,784
Wave/ Tidal/ Current	0	0	438	1,095	1,502	7,095	11,736	15,206	19,998
Nuclear	0	0	0	0	12,264	12,264	12,264	12,264	11,650
Hydropower	9,056	8,935	9,531	9,531	9,531	9,531	9,531	9,531	9,531
Geothermal	0	0	431	765	1,063	2,529	4,244	6,348	8,636
Fossil Fuel	124,596	134,719	149,521	157,365	147,518	132,450	99,164	39,648	-2,104
Total	134,468	145,547	164,675	186,316	198,536	226,237	257,577	293,036	334,439

Figure 3.4-3 Projection on electricity generation by energy source of Scenario-1 from 2012 to 2050

Hydrogen Generation Contribute to Fuel Cell

In order to create a carbon-free energy future, OTEC, wave, tidal current, solar PV and nuclear energy are the proposed resources that will be used for hydrogen generation. It is expected that the facilities to support the hydrogen economy will be completed in 2050. Hence, between 2030 and 2050, there will be a rapid growth in hydrogen generation.

The proposed capacities in Figure 3.4-4 are accounted for 55%, 30%, 20% and 5% of total installed capacities from OTEC, wave and tidal current energy, solar PV and nuclear energy, respectively. All of these resources are expected to contribute a total amount of about 35 MW in hydrogen generation.

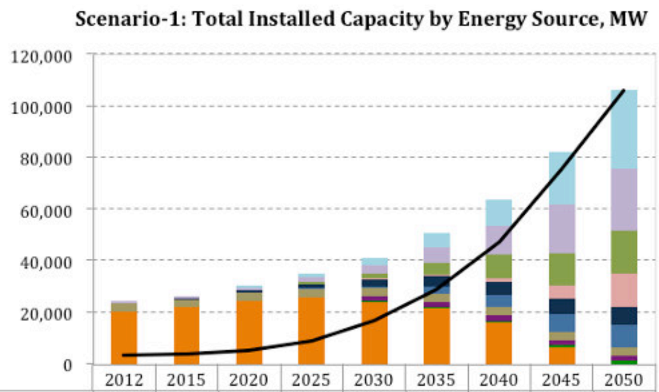


	2020	2025	2030	2035	2040	2045	2050
OTEC	3	128	500	1,000	2,000	6,000	12,000
Solar	0	0	0	300	1,000	2,250	4,000
Wind Energy	0	0	100	400	1,200	1,650	2,800
Wave/ Tidal/ Current	0	0	36	142	496	1,021	1,298
Nuclear	0	0	0	0	0	0	100

Figure 3.4-4 Installed capacity for hydrogen generation of Scenario-1 (2012 to 2050)

Total Installed Capacity

Figure 3.4-5 shows the capacities that need to be installed according to fuel types. A lower value of capacity factor needs a larger installed capacity. Therefore, in terms of installed capacity, wind and solar PV will be the dominants even though OTEC is expected to be the main source for electricity generation by 2050.



	2012	2015	2020	2025	2030	2035	2040	2045	2050
OTEC	0	0	20	850	2,500	5,000	10,000	20,000	30,000
Solar PV	6	357	801	1,502	3,005	6,307	11,012	18,763	24,000
Wind Energy	0	0	250	1,000	2,100	4,400	9,200	12,650	16,800
Fuel Cell	0	0	36	57	241	626	1,448	5,286	12,908
Bioenergy	270	470	694	1,533	2,826	4,089	4,838	5,813	6,865
Wave/ Tidal/ Current	0	0	200	500	722	2,842	4,962	6,807	8,907
Hydropower	3,040	3,000	3,200	3,200	3,200	3,200	3,200	3,200	3,200
Nuclear	0	0	0	0	2,000	2,000	2,000	2,000	2,000
Geothermal	0	0	66	116	162	361	606	906	1,232
Fossil Fuel	20,319	21,970	24,384	25,663	24,057	21,600	16,172	6,466	-343
Total CF (MW)	3,317	3,827	5,266	8,759	16,755	28,825	47,265	75,425	105,912

Figure 3.4-5 Total installed capacity by energy source of Scenario-1 (2012 to 2050)

Carbon Free Energy in Diverse Future Energy Mix

In this scenario, carbon-free energy sources have been introduced, and by 2050, fossil fuels will be completely phased out and replaced by eight types of alternative fuels in the energy mix:

1) Among these resources, OTEC with an estimated capacity factor of 0.9 is expected to be the main resource. Hence, compromising about 41% of electricity generation mainly, for the production of hydrogen.
2) Wind energy would be the second major resource for electricity supply. The wind energy is generated from on and offshore facilities.
3) Combined wave and tidal current energy will be the next important resource for electricity generation.
4) With regard to solar PV, although its technology and market have been well developed, the low capacity factor remains a constraint due to the availability of resources (4 hours during daytime only). Nonetheless, the peak performance operational time of solar PV – midday – happens to be also the peak demand time of the day. This gives an advantage to solar PV to supply for peaking loads.
5) Presently, the main source for bioenergy

in Malaysia is biomass from the oil palm industry. However, the wastes of the oil palm can also be converted into value-added products such as fertilisers and animal feedstock which generate more income. It is not extensively used as an energy resource for electricity generation. Hence, it is expected that the main source for bioenergy in electricity generation will be municipal solid waste and biogas despite the abundance of oil palm wastes from the oil palm industry.

6) The first nuclear power station is planned for 2021. In this report, it is assumed that a total of 2 GW nuclear power plants will be in place by 2025. This energy resource helps in supplying non-carbon electricity in the medium-term action plan due to the fact that other alternative resources might take a longer time to be developed.
7) Hydropower plants in Malaysia are mainly commissioned for large-scale electricity generation. The operational capacity needs to be controlled with regard to the environment impact. Hydropower has been used as peaking plants and for reserve margin. These strategies will be continued for the future energy mix.
8) Geothermal is relatively a new technology in Malaysia. The lack of expertise and experience means it will take a longer time to develop its technology. In addition, suitable sites for geothermal are limited in Sabah. These combined factors causes it to have smallest share in electricity generation.

Carbon Dioxide (CO_2) emission avoidance

The main impact of a carbon-free future will be a reduction in CO_2 emissions. Figure 3.4-6 shows the projected emissions from 2012 to 2050. The calculation is based on an emission factor of 1 MWh equivalent to 0.63 tonnes of CO_2 at present power generation mix (KeTTHA 2008). The negative values indicate the amount of CO_2 emissions avoidance compared to the present generation mix.

The projections show that between 2035 and 2040, the present proposed energy mix will be able to achieve a net zero CO_2 emission in the electricity sector. Furthermore, in 2050, the total avoidance is about 217 Gtonnes of CO_2. This amount is equivalent to carbon sequestered by about 170 billion acres of forest in a year or approximately the amount of emissions avoided from 106 petagrams of coal burned (US EPA).

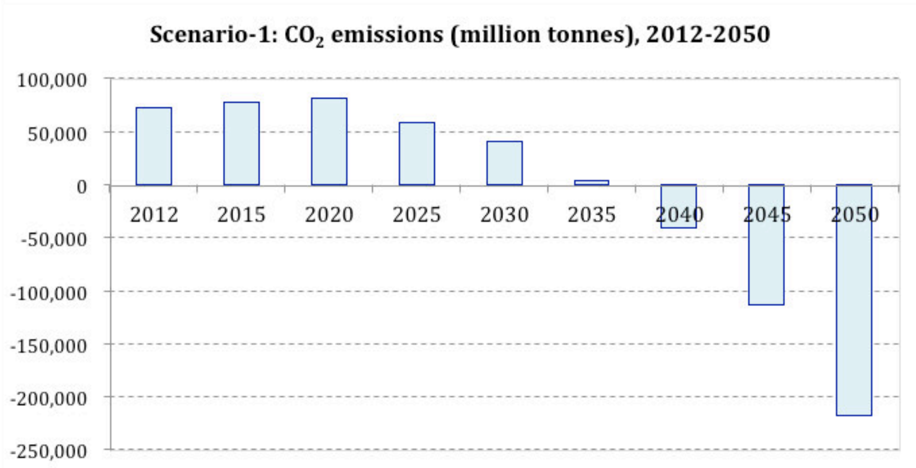


Figure 3.4-6 CO_2 emissions from the electricity generation of Scenario-1 (2012 to 2050)

3.4.2 Scenario-2: Net Zero Carbon Emissions

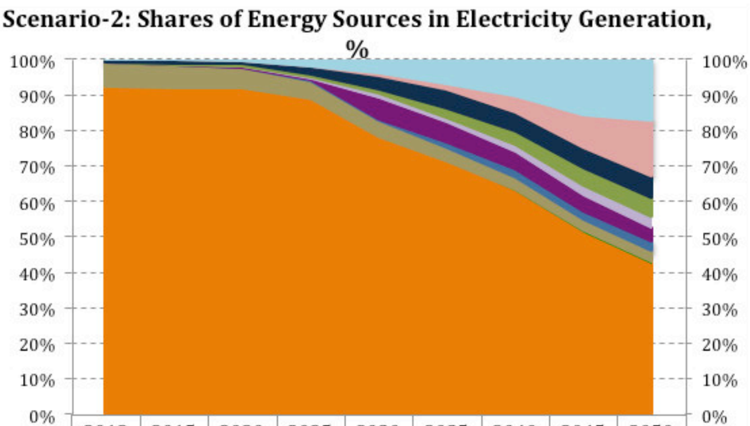
In this scenario, the total carbon dioxide emission avoidance from carbon-free energy sources will offset emissions from fossil fuel combustion by 2050.

Direct Electricity Generation

With regard to this, fossil fuels used in electricity generation will need to be gradually reduced from 97% (in 2012) to about 42% (Figure 3.4-7) by 2050. On the other hand, Figure 3.4-8 shows electricity generation in GWh by different types of energy sources from 2012 to 2050. Among the carbon-free energy sources, OTEC is expected to be a major source from 2035 to 2050, while fuel cell contribution will increase and become the second important source in 2045 with only 2% difference compared to OTEC in 2050.

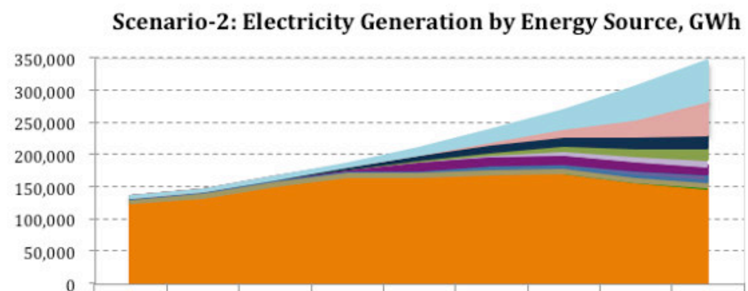
Hydrogen Generation Contribute to Fuel Cell

In order to have energy mix patterns as shown in Figures 3.4-7 and 3.4-8, hydrogen generation is the key to meet the electricity generation target of fuel cell. Therefore, the amount of energy required to generate hydrogen needs to be taken into account. In this scenario, energy sources that are expected to contribute towards hydrogen generation are as proposed in Figure 3.4-9, whereby the sources are diversified and the installed capacities increase from 2020 to 2050. The proposed installed capacities were calculated based on the electricity generation targets of fuel cell.



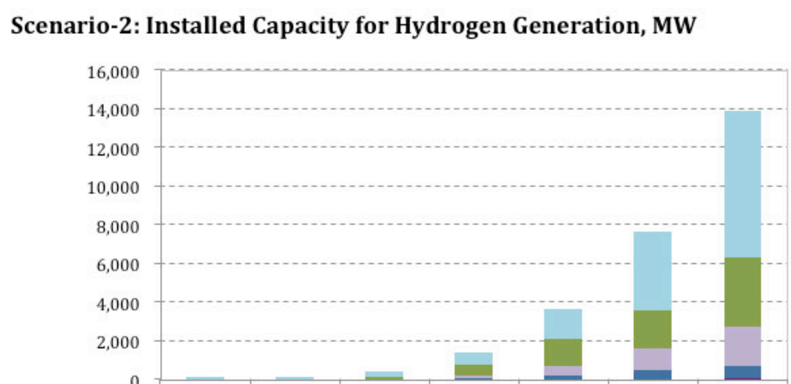
	2012	2015	2020	2025	2030	2035	2040	2045	2050
OTEC	0.0	0.0	0.1	1.5	3.7	6.6	10.2	15.5	17.1
Fuel Cell	0.0	0.0	0.0	0.2	0.8	1.7	4.3	9.1	15.4
Bioenergy	0.6	1.0	1.0	2.2	3.6	5.3	5.5	5.8	6.1
Wind Energy	0.0	0.0	0.3	0.6	1.2	2.5	3.7	4.8	5.5
Solar PV	0.0	0.3	0.5	0.8	1.2	1.7	2.3	3.1	3.4
Nuclear	0.0	0.0	0.0	0.0	5.8	5.1	4.5	4.0	3.4
Wave/ Tidal/ Current	0.0	0.0	0.1	0.3	0.4	1.5	2.2	2.5	2.8
Hydropower	6.7	6.2	5.8	5.1	4.5	4.0	3.5	3.1	2.8
Geothermal	0.0	0.0	0.1	0.2	0.3	0.5	0.8	1.0	1.3
Fossil Fuel	92.7	92.5	92.1	89.0	78.5	71.1	62.9	51.0	42.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Figure 3.4-7. Proposed shares of energy sources for electricity generation of Scenario-2 (2012 to 2050)



	2012	2015	2020	2025	2030	2035	2040	2045	2050
OTEC	0	0	134	2,848	7,884	15,768	27,594	47,304	59,129
Fuel Cell	0	0	16	354	1,665	4,054	11,603	27,782	53,194
Bioenergy	809	1,455	1,567	4,088	7,553	12,535	14,832	17,823	21,049
Wind Energy	0	0	547	1,095	2,601	5,913	10,052	14,520	18,922
Solar PV	7	437	790	1,579	2,631	3,999	6,314	9,502	11,913
Nuclear	0	0	0	0	12,264	12,264	12,264	12,264	11,650
Wave/ Tidal/ Current	0	0	219	548	751	3,548	5,868	7,603	9,662
Hydropower	9,056	9,084	9,531	9,531	9,531	9,531	9,531	9,531	9,531
Geothermal	0	0	216	382	531	1,264	2,122	3,174	4,318
Fossil Fuel	124,596	134,571	151,656	165,891	165,388	169,623	169,661	155,798	146,047
Total	134,468	145,547	164,675	186,316	210,800	238,500	269,841	305,300	345,417

Figure 3.4-8. Projection on electricity generation by energy source for Scenario-2 (2012 to 2050)



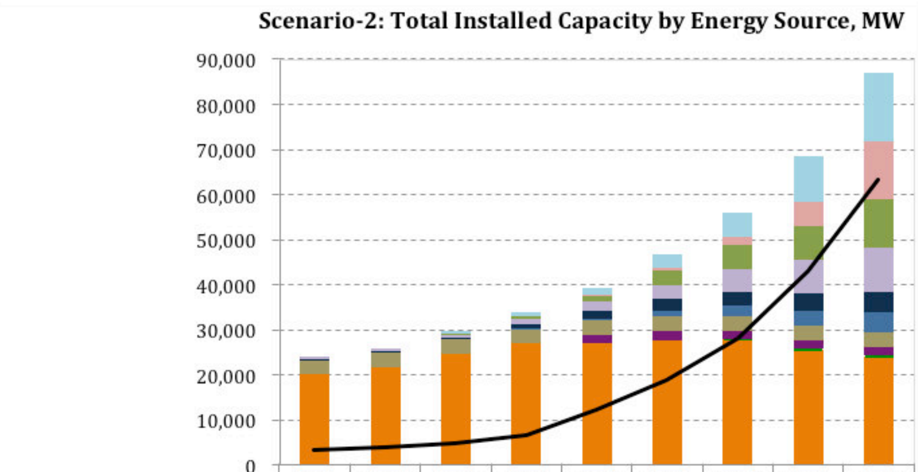
	2020	2025	2030	2035	2040	2045	2050
OTEC	2	64	250	500	1,500	4,000	7,500
Wind Energy	0	0	125	600	1,350	1,950	3,600
Solar PV	0	0	0	150	500	1,125	2,000
Wave/ Tidal/ Current	0	0	18	71	248	511	649
Nuclear	0	0	0	0	0	0	100

Figure 3.4-9. Installed capacity for hydrogen generation for Scenario-2 (2012 to 2050)

Total Installed Capacity

Figure 3.4-10 shows the total capacities that need to be installed to meet both electricity and hydrogen demands. This energy mix in turn will require the installed capacity of fossil fuel in power generation to be reduced gradually from 86% (in 2012) to 27% by 2050, whereby fossil fuels and carbon-free energy sources account for about 23 GW and 63 GW, respectively.

It is anticipated that by the year 2040, total installed capacity from carbon-free energy sources will contribute almost as much as fossil fuels and become dominant from that particular year onwards. The diversified energy mix patterns in terms of installed capacities from 2015 to 2050 are illustrated in Figure 3.4-11. The figure shows contributions from fossil fuels as decreasing while the rest of the carbon-free energy sources are increasing. Moreover, the contributions of carbon-free energy sources to hydrogen generation is expected to match that of the fuel cell installed capacity.



	2012	2015	2020	2025	2030	2035	2040	2045	2050
OTEC	0	0	18	425	1,250	2,500	5,000	10,000	15,000
Fuel Cell	0	0	3	58	272	661	1,892	5,286	12,677
Wind Energy	0	0	250	500	1,313	3,300	5,175	7,475	10,800
Solar PV	6	357	601	1,202	2,002	3,003	5,005	7,505	10,000
Bioenergy	270	470	412	913	1,723	2,533	3,033	3,722	4,471
Wave/ Tidal/ Current	0	0	100	250	361	1,421	2,481	3,404	4,325
Hydropower	3,040	3,050	3,200	3,200	3,200	3,200	3,200	3,200	3,200
Nuclear	0	0	0	0	2,000	2,000	2,000	2,000	2,000
Geothermal	0	0	33	58	81	180	303	453	616
Fossil Fuel	20,319	21,946	24,732	27,053	26,971	27,662	27,668	25,407	23,817
Total CF (MW)	3,317	3,877	4,617	6,605	12,202	18,799	28,089	43,045	63,090

Figure 3.4-10. Total installed capacity by energy source for Scenario-2 (2012 to 2050)

Figure 3.4-11. Installed capacity in energy mix from (a) 2015 to (h) 2050

Carbon Free Energy in Diverse Future Energy Mix

In this scenario, fossil fuels together with nine carbon-free energy sources will contribute towards the future energy mix as follows:

1) Fossil fuels will play an important role in power generation, however, its share of electricity generation in 2050 (97%) will reduced by more than half (42%) compared to 2012.
2) Among the carbon-free energy resources, OTEC is expected to be the main source and will account for about 17% of electricity generation by 2050. Furthermore, 50% of its total installed capacity will be used in hydrogen generation by 2050, making it the main energy source for hydrogen generation.
3) Fuel cell will be the next important energy conversion system after OTEC. However, full cell will rely on other carbon-free energy sources that contribute to hydrogen production. The share of fuel cell for electricity generation (2020-2050) can only be achieved if the energy supply for hydrogen production is sufficient.
4) The capacity factor of bioenergy is higher compared to wind energy and solar PV. Moreover, electricity generation from the bioenergy is higher compared to wind and PV, although it has smaller amount of installed capacity. In this scenario, it is assumed that about 90% of municipal solid waste will be treated by incineration. Furthermore, municipal solid waste will contribute significantly in the electricity generation mix.
5) Wind energy will be the fifth major energy source for electricity generation by 2050.
6) Solar PV shares about the same amount of installed capacity as wind energy. However, electricity generation from PV is less than the wind because of the lower capacity factor.
7) Nuclear energy will supply the non-carbon electricity in the medium-term action plan. Nuclear energy technology is relatively more mature than other carbon-free energy sources in terms of big-scale commercial power plants. Hence, nuclear energy is able to ease the reduction of fossil fuel consumption when other carbon-free energy technologies are still in the developing stages.
8) The combination of wave energy and tidal current energy will be the next important source that can contribute to electricity generation.
9) Hydropower plants in Malaysia are mainly large-scale. It has been used as peaking plants and reserve margin. However, the operational capacity needs to be controlled to safeguard the environment.
10) Geothermal is relatively a new technology in Malaysia. The lack of expertise and experience means it will take a longer time to develop this technology. In addition,

suitable sites for geothermal are limited. These factors cause geothermal resources to having the smallest share in electricity generation.

Carbon Dioxide (CO_2) emission avoidance

The main impact of a carbon-free energy future will be reductions in CO_2 emission. Figure 3.4-12 shows the projected emissions from 2012 to 2050 for Scenario-2. The calculation is based on an emission factor of 1 MWh that is equivalent to 0.63 tonnes of CO_2 in the present power energy mix (KeTTHA 2008). In addition, incineration of a tonne of MSW is assumed to produce approximately a tonne of CO_2 (Nor, Tuan, & Saad 2009). Thus, the values in the figure indicate the net emission per year, based on the present energy mix.

The projections show that by 2050, the present proposed energy mix would be able to offset emissions from fossil fuel combustion and achieve a net zero CO_2 emission in the electricity sector. In 2050, the total avoidance is about 92 billion tonnes of CO_2. This amount is equivalent to carbon sequestered by about 75 billion acres of forest in a year or approximately the amount of emission avoided from 44 petagrams of coal burned (US EPA). Furthermore, the cumulative avoidance from 2012 to 2050 is about 327 billion tonnes of CO_2.

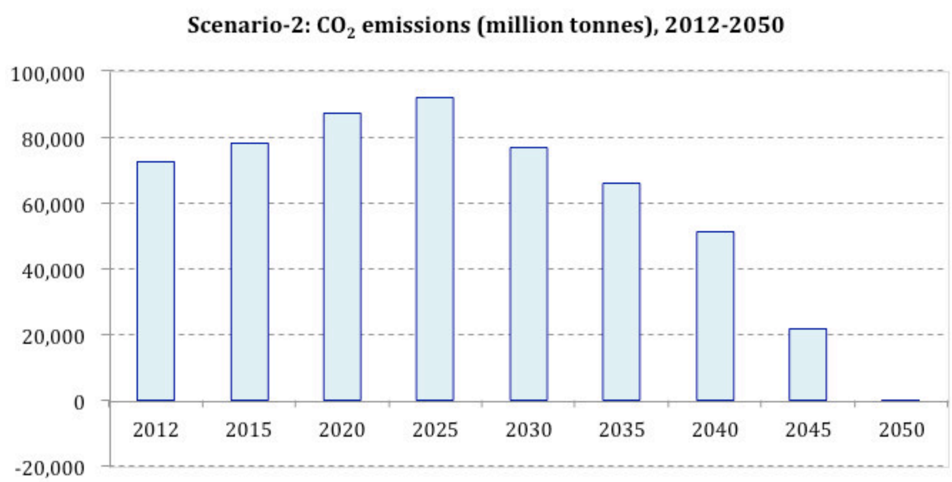


Figure 3.4-12. CO_2 emissions from electricity generation for Scenario-2 (2012 to 2050)

Chapter 4

Technology Development Roadmap: Action Plan and Time Frame

A carbon-free energy future is only achievable if all types of alternative fuels are developed and deployed within a specific time frame. The failure of any of these fuels in meeting the set milestones will delay or cause failure in achieving the roadmap targets. Cumulatively delay in achieving milestones will also create bigger gaps between actual progress and targets rendering targets impossible to be achieved within the earlier planned time frame.

The proposed action plan was developed using the backcasting approach, whereby the energy policy is directed towards achieving a net zero carbon emission in 2050 (Scenario-2). Actions that are required to achieve the roadmap targets were proposed and were classified into two, i.e. "Technology Development" and "Policy, finance, public acceptance and awareness".

4.1 Bioenergy

The Challenges

The main challenge for bioenergy is feedstock availability, which is biomass from the oil palm industry. Other issues related to feedstock include logistic and pricing. Currently, there is no market control in fixing prices and there is competition from other non-energy usage. There is also no existing technical standard for the industry.

Furthermore, due to low efficiency, the existing technology is yet to reach the maturity for commercialisation. High capital expenditures (capex), poor financing and funding systems also hinder the technology from being introduced into the market. There is also no appropriate business model in addressing issues related to banking. In general, the general perception of bioenergy that it is an expensive with low incentive technology has made it unattractive to the industry.

Apart from that, the lack of local, skilled human resources has caused the overdependence on international experts for technical support. Very limited capacity building and technology transfer opportunities are made available for the locals.

Actions and Time Frame

Table 4.1 summaries the proposed action plan related to technology development and public policy within a given time frame for bioenergy.

Table 4.1. Proposed action plan and time frame for bioenergy

Bioenergy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Enhancement the 1st and 2nd Generation technologies[5] • Technology scanning and upgrading by homegrown expertise • Pursue the gasification of solid waste • Maximises resource utilisation efficiency (reducing energy intensity) • Carry out field / commercial trials • Implementing energy efficiency measures • Algae: to be utilised for higher value added non-energy applications • Biogasoline/bioethanol: To make the tech more cost competitive for larger scale • Modify engine design to effectively utilise biofuel without damage • Development of integrated biorefinery	• KeTTHA • Universities and research institutions • Industries	• More promotion and awareness raising programmes from the government • Development of standards • Train more skilled/ semi skilled manpower • Establish a platform for Public & Private partnership (4Ps) • Industrial based R&D project • Engagement of industry and Universities and research institutes at the early development stage • Establishing international collaboration and networking for technology and knowledge transfer	• MOSTI, INTAN, MOE, MOHE, MITI, KeTTHA • Industries	By 2020
• Enhancement of biorefinery concept • Development of entire value chain of biorefinery (utilisation, storage and distribution)	• Universities and research institutions • Industries	• Continuous efforts on nurturing and enhancing the local talents	• MOHE, INTAN, MOSTI	By 2030
• Locally produced enzyme • Strengthening fundamental knowledge related to process and material development	• MOSTI • Universities and research institutions • Industries	• Continuous efforts on nurturing and enhancing the local talents	• MOHE, INTAN, MOSTI	Integrated biorefinary by 2040
• Practices related to the technology improvement	• Universities and research institutions • Industries	• Continuous efforts on nurturing and enhancing the local talents	• MOHE, INTAN, MOSTI	By 2050

[5] 1st Gen refers to direct combustion such as solid biofuel, carbonisation, trans/ esterification, anaerobic digestion and Bio-CNG; 2nd Gen refers to gasification, torrefaction, pyrolysis, biochar, bioethanol/ fermentation, biobutano and biogasoline

4.2 Geothermal

The Challenges

The first geothermal project in Malaysia is currently being spearheaded by an IPP, Tawau Geothermal Energy (TGE) since 2012. A working group on geothermal in Sabah has been established. The first exploration phase will be carried out at Apas Kiri in Tawau, where 12 km^2 of sub-surface heated water field has been discovered. The production capacity increases with the depth of the production well.

According to the reservoir management plan, a well with a capacity of 36 MW at a depth of 2.5 km will be built. It is expected to mitigate 200,000 tonnes of CO_2/year. In addition, the electricity generated will be sold to SESB under a 21-year Purchase Agreement. The main challenges of the geothermal technology include know-how stakeholder involvement from the Minerals and Geoscience Department Malaysia (JMGM), SESB and universities as well as limited financial support from the state government.

Actions and Time Frame

Table 4.2 summaries the proposed action plan related to technology development and public policy within a given time frame for geothermal.

Table 4.2 Proposed action plan and time frame for geothermal

Geothermal				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Increase R&D Funding • Increase in number of researchers and experts	• Universities and research institutions • JMGM	• Include geothermal subjects in the local university curriculum • Enhance training and education • Setting up of demonstration plant • Build 30 MW commercial plant for electricity • Participate in ASEAN Geothermal working group	• JMGM, MOHE, MOSTI, EPU, • TNB, SESB, SEB • Industries	First exploration to be completed By 2020
• Explore new sites/ surveys to meet the target • Optimise technology to reduce exploration cost (including drilling) • Ensure sustained funding from federal government • Research to further improve plant efficiency/ by-product usage	• Universities and research institutions • JMGM, MOSTI, EPU, • Industries	• Create a Geothermal unit/ hub under Sabah state government • Supply district water heating to surrounding residence • Include geothermal in FiT and Green Technology Financing Scheme (GTFS) • Include geothermal in RMK • Scale up 2nd geothermal 30 MW power plant • Strengthen skilled workforce along the geothermal value chain (training programs) • Develop Geotourism in Tawau • Establish international R&D collaboration	• SESB, SEB, TNB, • Local Government Agencies, EPU, • Industries, • ASEAN Geothermal Working Group	By 2030: An one-stop-centre or incubator to be created as a database for exploration; utilisation of the by-product
• Scale up two geothermal power plant of 30 MW • Tax incentives for investors/manufacturers for fabrication of steam turbine systems	• Universities and research institutions • JMGM, MOSTI, EPU, • Industries	• Enhance capacity building and awareness programmes for technical support in local technology • Create MoU to further integrate transfer of knowledge	• TNB, SESB, SEB • Local Government Agencies, EPU, • Industries, ASEAN • Geothermal Working Group	By 2040: Development of local technology; In crease market share through further exploration in ASEAN region
• Technology improvement, including cost reduction to compete with other technologies	• Universities and research institutions • Industries • SESB • ASEAN Geothermal Working Group	• Technology transfer to other countries	• Universities, ASEAN Geothermal Working Group	Additional two geothermal power plant of 30 MW Each by 2050

4.3 Hydropower

The Challenges

At the present, the total installed capacity of hydropower plants is 5,421 MW, of which 5,000 MW is from major plants and 21 MW is from mini and micro hydropower plants. The main issue of hydropower is its impact on the environment. Large hydropower plants create large inundated areas. For instance, the Bakun project required a land area equivalent to Singapore. In Malaysia, the installed capacity is larger than the demand, whereby the current capacity factor is only about 0.34.

Large hydropower plants also tend to cause intensive deforestation and population displacement that not only damage the ecosystem but also involves high capital investment. Therefore, the mapping of any possible site should take into account flora and fauna preservation. Other challenges include limited local resources in turbine system turbo machinery design and also the effects on freshwater utilisation.

Actions and Time Frame

Table 4.3 summaries the proposed action plan related to technology development and public policy within a given time frame for hydropower.

Table 4.3 Proposed action plan and time frame for hydropower

Hydropower				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• New concept of reservoir such as run on river concept (damless) • Forecasting and optimisation of water resource • Improve part load turbine efficiency • Reduce hydro kinetic energy loss • Use variable-speed pump turbines for PSP projects to provide greater variability 2015-2020 • Develop seawater PSP in conjunction with offshore resources (wind power, marine power) 2020-2050 • To develop methods in neutralising dissolved H_2S and methane generated from decomposition of organic matters for new reservoirs • Integrating instream hydro turbine with town water supply • Establish a Dam networking system, i.e dams supplementing water among each other for the states water grid project.	• Universities and research institutions • NAHRIM, JPS, ST, • Industries	• Implement Stage by stage Run on river deployment in rivers of Malaysia • Introduce private public partnership incentives • Revenue from logging should be compensated back to the hydro project & community. • Preparation of industry to produce local parts for on river hydro system • Construction of three major hydro plants, with capacity of 2,000 MW each. • Deployment of mini hydro power plants of 50 MW • Acquire technology partner from abroad in developing hydro system • Develop pump storage power plant application for energy security • Establish policy and regulatory frameworks to i) update hydropower inventories ii) review targets for hydropower development, including upgrade and redevelopment of old HPP and additions to existing dams and waterways iii)streamline permit processes while maintaining the highest level of sustainability requirements iv)update and adjust hydropower targets	• JPS, NRE, KeTTHA, MOSTI, MITI, ST, • TNB, SESB, SEB	By 2020

Hydropower				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Pump Storage from abundant mines/reservoirs	• Universities and research institutions • NAHRIM, JPS • Industries	• Three more major dams to be constructed to meet demand @ 2000 MW each • One pump storage Hydro plant @ 5 MW • Deployment of mini hydro /instream 100 MW	• JPS, NRE, KeTTHA, MOSTI, ST, • TNB, SESB, SEB, • Industries	By 2030
• Develop future materials for new generation dam construction • Develop water cycle regulation (storing water in clouds)	• Universities and research institutions • NAHRIM, JPS • Industries	• Four More major dams to be constructed to meet demand @ 2000 MW each • Two pump storage Hydro plant @ 10 MW each	• JPS, NRE, KeTTHA, MOSTI, ST, • TNB, SESB, SEB, • Industries	By 2040
• Miniaturisation of hydro power systems	• Universities and research institutions • Industries	• Three More major dams to be constructed to meet demand @ 2000 MW each	• JPS, NRE, KeTTHA, MOSTI, ST, • TNB, SESB, SEB • Industries	By 2050

4.4 Nuclear Energy

The Challenges and Actions

The main challenges of nuclear energy include public acceptance, lack of local experts and operational workers, development of legal infrastructure and financing issue. Table 4.4 summarises the challenges and proposed actions by Nuclear Malaysia (Abu 2011).

Table 4.4 Challenges and potential resolutions of nuclear energy

	Challenge	Potential resolution
Public Acceptance	▪ Promote public acceptance	▪ Public opinion survey to identify priority segments & concerns ▪ Awareness projects ▪ Transparency in project implementation
International Governance (IAEA.org)	▪ Sign/ratify relevant treaties & conventions	▪ Fast-track process and make government priority
Regulatory Context	▪ Put in place detailed regulations	▪ Align on international best practices ▪ Top-down mandate to accelerate process ▪ Engage foreign experts to assess site & construction permit applications
Nuclear Plant Site Acquisition	▪ Acquire approval for plant sites ▪ Obtain public support in locality	▪ Public information programme ▪ Option for localities to bid to host nuclear plants as in Japan & Republic of Korea
Construction Timeline	▪ Require best-in-class timeline from vendors	▪ Negotiate with vendors based on timeline
Project Financing	▪ Obtain low-cost financing	▪ Combine low-cost & market financing (e.g. sovereign-guaranteed foreign export credits, foreign equity, commercial loans, including Islamic financing)

Source: (Abu 2011)

4.5 Ocean Thermal Energy Conversion (OTEC)

The Challenges

There is no commercial OTEC power plant in Malaysia at the present. Attracting pioneer OTEC project developers and investors remains to be the main challenge. Moreover, there is also no corresponding agency in Malaysia for OTEC projects. Other challenges include the unknown impact on deep-water biodiversity as well as limited local operational knowledge and experience of commercial plants. Although OTEC incurs a high capital cost, this can be offset by much lower operating cost in the long run.

Actions and Time Frame

Table 4.5 summaries the proposed action plan related to technology development and public policy within a given time frame for OTEC.

Table 4.5. Proposed action plan and time frame for OTEC

OTEC				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Advance developments in nanotech for heat exchangers and working fluids	• Universities and research institutions • NanoMalaysia, • Industries	• Specific law on OTEC • Royalty payment for OTEC revenue. • An establishment of OTENAS[6] • C=>D=>R[7] Approach and not necessarily R=>D=>C way • Training and capacity building programmes on operational knowledge of commercial plant	• MOSTI, EPU, MOF, KeTTHA, NRE, INTAN, MOE	First power plant by 2020
• Selection of high value marine produce • Management of deep sea water	• Universities and research institutions • JLM, MET Malaysia, JUPEM, NRE • Industries	• Training and capacity building programmes on operational knowledge of managing voluminous amount of water • Establishment of ocean thermal energy technology parks	• MOSTI, INTAN, MOE, KeTTHA, NRE	Development of 3rd generation with nanotech plant by 2030

[6] Ocean Thermal Energy Nasional Sdn Bhd (OTENAS)
[7] C: commercialisation; D: development; R: research

OTEC				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Technology and knowledge transfer from other countries • Management of concession area for OTEC	• MITI, JLM, MOSTI, • Universities and research institutions • Industries	• Training and capacity building programmes on knowledge of competing uses of the deep seas • OTEC concession areas to coincide with oil and gas blocks	• MOSTI, INTAN, MOE, KeTHHA, NRE	By 2040
• Development of new materials for habitats and production of basic needs • Development of floating cities at sea - Design and adaptation of living at floating cities	• MOSTI • Universities and research institutions • Industries	• Legal status and birth registration of the new floating city communities • Anchoring the floating cities near to sub aerial features	• MOSTI, MOHE, JPN, MOHA	By 2050

4.6 Solar Photovoltaic (PV)

The Challenges

The photovoltaic (PV) cells that are commercially available are mainly silicon-based and thin film (CdTe) solar cells. As of April 2015, the total installed capacity of solar PV under the FiT mechanism is about 192 MW (SEDA 2015). The high cost of capital investment, low electricity tariffs and limited quota for solar project applications under the FiT programme are hindering the potential growth of the PV market. Furthermore, at the present, the Malaysian market is depending 100% on imported solar cells. The lack of skilled installers and industry-academic linkages are also among the issues that need to be addressed.

Actions and Time Frame

Table 4.6 summaries the proposed action plan related to technology development and public policy within a given time frame for solar energy.

Table 4.6 Proposed action plan and time frame for solar energy

Solar Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Improve processing and performance 1st generation solar cells • R&D for PV system • Development of advanced solar technology (3rd generation glass-based solar)	• Universities and research institutions • Industries	• More funding for R&D in advanced solar technology • More allocation for training • Incorporate EE and RE in School curriculum • Introduce life-long learning: awareness and technical knowledge • Produce more competent technicians and designers • Policy of utility: Revise quota system • Introduce indirect Feed-In for PV system • Enforcement of standards for PV installations • Provide more incentives for solar-based industry • Develop local solar manufacturer • Increase R&D funding and infrastructure for advanced technology • Develop local resources for nanostructure solar cells	• MOE, MOHE, MOSTI, KeTTHA, SEDA, ST, MGTC, MDV, SIRIM, MIDA, INTAN • TNB, SESB, SEB • Schools, Polytechnics, Universities, training institutions • Industries	By 2020: 10% of residential; 10% of government and 10% of non-government commercial buildings
• Development of advanced solar technology (future solar panel e.g. flexible panel)	• Universities and research institutions • Industries	• Incentives for utilisation of solar for residential • Introduce academic programmes at universities focusing on advanced material for solar cell • Life-long learning programme – awareness, energy efficient lifestyle, technical knowledge • Continue competency training programme for PV system integrators • Develop local resources for future generation solar cells	• MOE, MOHE, MOSTI, KeTTHA, SEDA, ST, MGTC, MOHE, MDV, MITI, MOA, MOT, INTAN • TNB, SESB, SEB • Schools, Polytechnics, Universities, training institutions • FMM, Industries	By 2030: Reduce 20% dependency on imported solar cells and system components; 30% of residential; 30% of government and 30% of non-government commercial buildings; Contributions of 1% of energy use in industry 10% in agriculture and livestock; 5% in transportation

Solar Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Development of advanced solar technology (future solar panel e.g. environmental friendly, cleaner production)	• Universities and research institutions • Industries	• Continue lifelong learning programme for self-sustainable society • Provide infrastructure for solar powered vehicles • Provide incentives for industries to deploy solar technology	• MOE, MOHE, MOSTI, KeTTHA, SEDA, ST, MGTC, MDV, MIDA, MOT, JKR, MOHE, MOA, INTAN • TNB, SESB, Sarawak Energy • School, Polytechnics, Universities, training institutions • Industries	By 2040: Reduce 40% dependency on imported solar cells and system components; 40% of residential; 40% of government and 40% of non-government commercial buildings; Contributions of 2% of energy use in industry; 30% in agriculture and livestock; 20% in transportation
• Improved advanced solar technology (future solar panel e.g. environmental friendly, cleaner production)	• Universities and research institutions • Industries	• Export local panels to international market • Implement smart community concept	• MITI, MOHE, MOE, MOHE, MOT, JKR, MOA • NGOs and community associations • Industries	By 2050: Reduce 60% dependency on imported solar cells and system components; 60% of residential; 60% of government and 60% of non-government commercial buildings; Contributions of 3% of energy use in industry; 30% installation from agriculture and livestock; 40% installation from transportation; 10 GWhthermal/0.86 ktoe base on 20% total residential rooftop in Peninsular Malaysia in 2015

4.7 Wave Energy and Tidal Current Energy

The Challenges

These technologies are currently still at the research and development (laboratory) stage in Malaysia. The available laboratory prototypes include marine current turbine 1-2 MW (horizontal axis) and 1 MW technology from Europe and US. Local universities have been actively carrying out resource and device modelling activities; however, the capital investment costs are still high. Other challenges include technology and social issues.

Actions and Time Frame

Table 4.7 summaries the proposed action plan related to technology development and public policy within a given time frame for wave energy and tidal current energy.

Table 4.7. Proposed action plan and time frame for wave energy and tidal current energy

Wave Energy and Tidal Current Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Establishment and reinforcement in R&D programs into development of novel technology to provide reliable operation, device design: • Resource modelling • Device modelling • Experiment testing • Moorings & sea bed attachment • Electrical infrastructure • Power take off and control • Engineering design • Lifecycle and manufacturing • Installation O&M • Environment • Standard • System simulation • Innovation of technology of new components and subcomponents • Development of resource mapping for wave and tidal • Technology advancement such as synergy with wind etc. • Use existing technology for deployment of pilot scale 3-10 MW	• METMalaysia • Universities and research institutions • Industries	• Capacity building programmes to train local skillful workers • Assessment on environmental and social issues • Design, construction, and installation of 10 units of 2 MW wave generators • Establishment of tidal/ wave/current training centres	• MOE, MOSTI, INTAN, KeTTHA, KKLW, MOTAC, MOA	Installation of a total of 200 MW wave generators by 2020

Wave Energy and Tidal Current Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• R&D for next generation, 10 MW generator	• Universities and research institutions • Industries	• Design, construction and installation of 105 unit of 5 MW generators	• Industries	Installation of a total of 720 MW wave generators by 2030
• R&D for next generation, 20 MW generators	• Universities and research institutions • Industries	• Design, construction and installation of 418 of 10 MW generators	• Industries	Installation of a total of 4,900 MW generators by 2040
• R&D for next generation hybrid wave, tidal and wind generators	• Universities and research institutions • Industries	• Design, construction and installation of 200 units of 20 MW generators	• Industries	Installation of a total of 8,900 MW generators by 2050

4.8 Wind Energy

The Challenges

Wind energy technologies from UK, India, US, Taiwan and Netherlands have been tested, with maximum capacity factors achieved at 15% and 25% for onshore and offshore applications, respectively. At the present, the total installed capacity of onshore and inland wind energy is about 500 kW; however, there are no offshore applications in Malaysia. One of the challenges of this technology is the unpredictable wind behavior. An intensive study on wind mapping for Malaysia is currently being carried out and is expected to be completed in 2016.

This is important in order to develop technologies that suit the wind conditions in Malaysia. Furthermore, local universities have been actively carrying out R&D on low wind speed turbine, integrated wind augmenter to increase wind speed 1.5 and applications for wind-solar hybrid lamp post. Similar to other new technologies, the capex for wind technology remains high. Moreover, it is not included in the FIT mechanism until a specified energy density (offshore ~ 500 MW, onshore~100 MW) is determined.

Actions and Time Frame

Table 4.8 summaries the proposed action plan related to technology development and public policy within a given time frame for wind energy.

Table 4.8. Proposed action plan and time frame for wind energy

Wind Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• R&D on materials and corrosion • Scaling up turbine capacity • Development of lightning protection system • Establishment of site measurement for offshore	• Universities and research institutions • JUPEM • Industries	• Identify areas to install 250 units of 1 MW wind turbine • Propose and secure fund from public and private entities. • Form partnership with suitable technology provider. • Design, construct and install locally • Design and develop prototype of next generation wind turbine • Establishment of Wind Turbine Training Center to address the gaps in knowledge, specifically technology on low wind speed turbine technology • Development of supporting industries	• JUPEM, MOF, MDV, MOSTI, MET Malaysia, MITI, • Industries	Installation of a total of 250 MW by 2020
• R&D next generation of wind turbine (hybrid, high capacity, free maintenance, all weather condition) etc.	• Universities and research institutions • Industries	• Identification of locations • Design, construct and install 617 units of 3 MW wind turbine • Design of next generation prototype (all weather condition) • Design high capacity mobile wind turbines	• MET Malaysia, JUPEM, MOSTI, • Industries	Installation of a total of 2,100 MW by 2030
• R&D on high capacity hybrid wind turbine	• Universities and research institutions • Industries	• To find suitable locations • To design, construct and install 1,420 units of 5 MW all weather conditions wind turbines	• MET Malaysia, JUPEM, MOSTI • Industries	Installation of a total of 9,200 MW by 2040
• R&D on high capacity mobile wind turbine	• Universities and research institutions • Industries	• To find suitable locations • To design, construct and install 1,520 units of 5 MW hybrid generator	• MET Malaysia, JUPEM, MOSTI • Industries	Installation of a total of 16,800 MW by 2050

4.9 Fuel Cell and Hydrogen Energy

The Challenges

Fuel cell and hydrogen technologies are still mainly at the research and development stage in Malaysia. A small industry exists to cater to the needs of research institutions but is not strong enough to provide a supportive environment for potential stakeholders, and investors.

The basic mechanism for deployment of the fuel cell and hydrogen energy industries were put in place by the relevant government agencies but the lack of incentives to attract business owners and end users/customers have prevented a meaningful nationwide implementation of fuel cell and hydrogen energy projects. Other challenges include lack of awareness of the importance of fuel cell and hydrogen energy, high cost for imported raw materials, minimal capacity building efforts, and technological barriers due to intellectual property constraints.

Actions and Time Frame

Table 4.9 summaries the proposed action plan related to technology development and public policy within a given time frame for fuel cell and hydrogen energy.

Table 4.9. Proposed action plan and time frame for fuel cell and hydrogen energy

Wind Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Complete the development of the relevant sectors for components in hydrogen production, purification, and in alternative raw materials • Complete the identification of research, development, and deployment (RD&D) needs and priorities in targeted pilot projects for fuel cell applications • Domestic hydrogen production from the existing local hydrogen producers and resources • Installation of 78 fuel cell units to produce the targeted 200 GWh electricity generation	• Universities and research institutions • Industries	• Organise high profile awareness raising campaigns, which focuses on carbon dioxide emission problems and benefits of energy security. Aim the campaigns at politicians, policy makers and local planners as well as insurance, financial, and underwriting communities • Successfully raise awareness by encouraging fuel cell-based project learning in public education curriculum and work towards developing fuel cell courses at selected schools and universities • Include renewable hydrogen (used in fuel cells for electricity generation) in the current list of renewable energy qualified for the Feed-in-Tariff (FiT) program or any beyond the FiT program such as net metering at SEDA • Complete the development of nationally acknowledged credentials, benchmarks, and standards with a shared data base for fuel cell industry and suppliers • Register Malaysia as a member country for the ISO/TC 197 Hydrogen Technologies technical committee to develop local standards for hydrogen safety • Formulate policy decisions based on life-cycle analysis costs and evolving methodologies to account for external features and social benefits of fuel cells	• MOSTI, EPU, MOF, KeTTHA, NRE, INTAN, MOE, Energy Commission • Hydrogen manufacturers	By 2020

Wind Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Develop indigenous technologies in smaller and lighter hydrogen storage • Develop innovative capacity to obtain appropriate alternatives for convenient local technologies in fuel cell applications • Secure early adoption in competitive market applications focusing on back-up power (UPS) systems, distributed generation, and portable power systems • Total fuel cell installed of 291 units to produce the targeted 3000 GWh electricity	• MOSTI, MOE, NRE, KeTTHA • Universities and research institutions • Industries	• Fully update the stakeholder list for fuel cell and hydrogen industries with representatives from lawmakers, ministry and military personnel, coalition teams (government, industry, and academia), economic development agencies, energy and environmental agencies, business owners, university researchers, and enthusiastic end users/customers • Successfully channel the strengths of domestic champions to potential international stakeholders in order to stimulate inbound investment • Develop mechanisms that provide a supportive environment for potential stakeholders and investors to convey a consolidated stance in the local and global markets • Collaborate with early adopters that agree on premium payment from strategic partners in different agencies, institutions, and market segments • Secure appropriate support framework to stimulate a sizable local deployment of fuel cells in diversified applications and situations • Secure partners from government agencies and original equipment manufacturers (OEM)/end users to cost share in market demonstrations and early applications • Develop a strong network linking related technical facilities to a central fuel cell cluster	• MOSTI, INTAN, MOE, KeTTHA, NRE, TNB, GreenTech Malaysia	By 2035

Wind Energy				
Technology Development		Policy/ finance/ public acceptance/ awareness/ collaboration		Time frame
Actions	Targeted Stakeholders	Actions	Targeted Stakeholders	
• Complete the development of islanding systems around fuel cell-powered DG installations • Integrate a renewable energy-based system to assist in producing hydrogen for a centralised or distributed energy facility to supply power • Power all security lighting (crime-prevention lamps) and street lamps with fuel cells • Plan urban development as a whole, including the next generation transportation system, lifestyle and business opportunities • Locally mass-produce the materials and components required for producing fuel cells in order to reduce cost and nurture cost-reduction certainty • Total fuel cell installed of 2772 units to produce the targeted 50000 GWh electricity generation	• Relevant ministries and government agencies • Universities and research institutions • Industries	• Install effective mechanisms for information dissemination to relevant regulatory bodies regarding the adopted codes and standards for Malaysia • Formulate a business model that is capable of selling fuel cell at a discount but with sufficient volume secured to reduce payback time and increase return of investment after 3 years • Implement investment and development plans for local component production that will be monitored and reviewed continuously • Successfully involve fuel cells in the Malaysian market by utilising high profile infrastructure development plan • Install subsidy mechanisms to replace the residential power system with fuel cells in order to reduce GHG emissions in the residential sector • Attain full government cooperation as an early adopter of fuel cell technology for a range of high profile applications • Complete the cultivation of political initiatives to focus the government in fuel cell-related obligations	• MOSTI, INTAN, MOE, KeTHHA, NRE • Industries • Schools and universities • Media agencies • Industries	By 2050

Chapter 5

Conclusions and Key Messages to Decision Makers

Based on the findings, the task force would like to propose Scenario-2 to be adopted as the Carbon-Free Energy Roadmap for Malaysia. In this scenario, "Carbon-Free Energy" is referenced to "the total carbon dioxide emission avoidance from carbon-free energy sources that will offset the emissions from the fossil fuels combustion by 2050 in energy mix".

Key measures that the team would like to highlight to decision makers are as follows:

1. **Increase the share of renewable energy (RE) in the energy mix by setting long-term targets for RE deployment, consistent with national energy strategies and national contributions to global climate change mitigation efforts.**

2. **Explore the potential of RE resources of wind, OTEC, wave and tidal current, and geothermal.**

3. **Explore fuel cell technologies, including the potential of large-scale applications (power plant) for hydrogen economy in the future.**

4. **Strengthen research and development, knowledge and technology transfer through international collaboration, demonstration and deployment in local context.**

5. **Establishment of RE consortiums to facilitate the development of technologies.**

6. **Enhance personnel capacity in RE through training courses, university and school curriculums.**

7. **Advanced planning of new RE plants and thus address issues related to land use and sea use planning.**

8. **Develop a finance mechanism that would attract and aide renewable energy project developers.**

9. **Integrate energy policy with national mitigation and adaptation plans to address climate change issues.**

10. **Strengthen the institutional framework in planning, implementing, monitoring and evaluating the policies and projects related to energy and climate change mitigation.**

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