# MEGA SCIENCE 2.0
SECTORAL REPORT

# ENVIRONMENT

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# MEGA SCIENCE 2.0

## Environment Sector

AKADEMI SAINS MALAYSIA

# Contents

**CHAPTER 4: ENERGY**

# FOREWORD

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

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

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

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

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

# PREFACE

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

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

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

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

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

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# ACKNOWLEDGEMENT

## THE ENVIRONMENT SECTOR STUDY TEAM

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

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# EXECUTIVE SUMMARY

## MEGA SCIENCE 2.0 | ENVIRONMENT SECTOR

This report aims to provide an overview of the major environmental issues that affect Malaysia. They include carbon and climate change and the management of water, energy, waste, land and forests. Until a few years ago, the climate was considered too big for humans to manage, and water, energy, waste, land and forests were considered national issues of no concern to the rest of the world. Within Malaysia, water, land and forests were treated as State resources and managed by separate authorities with little or no consultation among themselves. This environmental paradigm now has to be reassessed in the light of new environmental realities affecting the country and the world.

Climate change is the result of global warming caused by the increase in greenhouse gases especially carbon dioxide, released primarily by the generation of energy through combustion of coal and hydrocarbons and also by the clearing of forests, which results in the carbon stored in forest vegetation and soils being released as carbon dioxide. The forces that drive the generation of energy and the elimination of forests globally are the rapid increase in human population, from below 2 billion at the start of the 20th Century to 6 billion at the end of the century. The global population is expected to reach 8 billion by 2030 and 9 billion by 2050. The present trajectory of economic development coupled to environmental degradation is clearly leading towards global disaster. Environmental issues are intimately connected with each other and cannot be viewed in isolation. The challenge we face is to find ways to develop without negative consequences and to undo the negative consequences that have accumulated. To face this challenge we need to understand the environment as a whole and not as separate sectors unrelated to each other.

Hence, to safeguard our environment, new technologies will be very important but will not be enough if old bad habits remain unchanged. Bad habits resulting in wasteful use of water and energy, proliferation of waste, misuse of rivers and oceans as rubbish dumps, and the clearing of forests in the single-minded pursuit of profit, are rooted in personal perceptions. A very large part of environment management will involve the management of human perceptions and behaviour, in which political and social leadership will play vital roles.

**Climate change**: Climate change is now at the top of the global environmental agenda. The global climate regime, although complicated and highly variable from season to season and place to place, is nevertheless the result of a balanced equilibrium that has been maintained for thousands of years.

This equilibrium is being upset by the recent rapid build-up of greenhouse gases in the atmosphere. Even a small rise of $2^{oC}$, now believed to be inevitable, will result in a large increase in the rate of evaporation of water into the atmosphere, and cause abnormal rainfall and wind patterns. The intensity and frequency of storms, droughts and other climatic extremes have been increasing steadily over the past few decades. The thinning of ice caps is causing the ocean level to rise. A substantial proportion of the carbon dioxide that goes into the atmosphere passes into the ocean and increases the acidity of the water. The rise in ocean acidity is a threat to marine life and endangers the marine food chains that support human food security.

The principle greenhouse gas is carbon dioxide, which is emitted by all living organisms in respiration, but the amount emitted in biological respiration is normal. What is abnormal is the additional amount that has been emitted since the start of the Industrial Revolution in the mid-1700s in Europe, when human and animal muscle power began to be replaced by engines powered by the combustion of coal and hydrocarbons. The world now runs on electricity generated mostly by combustion of coal, and on engines powered by the combustion of petroleum.

To counter the effects of climate change, the countries of the world have agreed to establish targets for reduction of greenhouse gas emissions, to be implemented in 2020. Some countries, especially those in the European Union, are moving ahead with targets of their own. The reduction of emissions can be effected in a number of ways: (a) by more efficient and frugal use of energy (b) by increasing the use of non-fossil energy alternatives such as solar, wind and nuclear power (c) by substituting fossil fuels with renewable fuels such as wood and other biomass and (d) by reducing and reversing deforestation.

The amount of greenhouse gases emitted or "carbon footprint" for each activity can be calculated. The MYCarbon initiative in Malaysia is designed to encourage organisations to voluntarily declare and monitor their carbon footprints. This is expected to increase corporate and public awareness and lead to more voluntary reductions. It needs to be emphasising that good leadership is needed to promote voluntary reductions. What government can do is to provide incentives for positive efforts. Taxes on emissions could be eventually be imposed.

Therefore, Malaysia should establish a wood-pelleting industry to replace imported coal with local-grown wood for the generation of electricity. Such an industry will not come into existence unless a complete system is put into place that would include wood-growers, wood-pelleting plants, wood-using power generation plants, and facilities for collection, transportation, research and development. To initiate and manage such a system the establishment of a suitably empowered Carbon Authority would be necessary.

In Europe, the use of wood pellets to replace coal for generation of electricity is given top priority but in Malaysia there has been surprisingly little or no attempt to develop an industry dedicated to the production of wood to replace coal for electricity generation. Instead, attention is being given to nuclear energy even though the conditions for growing trees in Malaysia are much better than in Europe, and growing trees would be much more popular than other alternatives. The combustion of wood and other forms of biomass would emit CO2 but the amounts emitted would be reabsorbed by new plant growth, hence the net emission would be zero.

**Water**: Water has so far been plentiful in Malaysia, but shortages are being experienced in certain places and at certain times due to increasing demand and rapid growth of urban populations. The abundance of water in the past is reflected in the way water is consumed. The per capita consumption of water in Malaysia is 2,103 m3/annum, which is much higher than the global average of 1,385 m3/annum.

The volume of water used to produce a product over the whole of its supply chain is known as the water footprint of the product. There is no national database on the water footprints of Malaysian agricultural and industrial products but it is expected that the water footprints of, our agriculture and industrials products would be relatively high.

There has been a tendency to treat the rivers as drains into which sewage can be freely dumped; to be flushed out to the sea. Generalised or 'non-point' pollution in the form of eroded soil is responsible for the silting up of dams and the raising of river beds, requiring expensive de-silting measures. Fertiliser pollution due to leakage from plantations and farms contributes to proliferation of algae and decline of dissolved oxygen levels required by fish and other aquatic life. The range of new pollutants from the healthcare, agricultural and manufacturing industries has been increasing and their long term effects when flushed into the rivers are mostly unknown. Water pollution control requires innovation, particularly the innovation of automated monitoring equipment that can be installed in all major riverine systems to help detect sources of pollution. At present, most monitoring is based on manual sampling.

In view of uncertainties in rainfall distribution due to climate change, water now has to be regarded as a precious resource, to be managed and used carefully. At present, a lot of water is lost through leakages and theft from the distribution network. The rate of water leakage varies from 17.6% in Penang to 66.4% in Perlis, with an average of 30%. Most pipelines are over 40 years old and need renewal. Technologies are needed for efficient detection of leaks and there should be a phased and sustained programme to renew old pipelines.

Conventional ways to meet growing demands for water through structural works such as dams, treatment plants and distribution systems and through interstate transfers will reach a limit and other methods will have to be developed. Wastewater recycling, groundwater development, rainwater harvesting, storage of flood water and desalination of sea water are important options that need to be developed.

Although Malaysia is rich in groundwater, knowledge of the quantity, distribution, and limits of sustainability have to be researched.  Hence, more attention has to be given to ground water tapping and to the saving of rainwater for local use by storing or by encouraging it to sink into the ground. In dry weather, the soils dry out too quickly, putting our crops, parks and gardens at risk. Property developers could do more to increase the surface area for rain water to percolate into the soil. New designs for pavements and drains are needed.

The wetlands of Malaysia are used to function as flood-control and water-retention areas, nonetheless,the drainage of vast areas for oil palm agriculture has reduced the areas of wetlands drastically. As a result, it may be necessary to create new wetlands as water storage and flood-control facilities. The desalination of sea water is being given high priority is the Middle East, Singapore and other areas that have a shortage of water. Thus, any breakthroughs that could reduce the cost of desalination would have a ready world market. All polluted rivers should be cleaned up and all rivers managed as pollution-free waterways by 2030. Clean river basins are already the norm in Japan and Korea. There is no technological excuse for lagging behind. Enforcement may involve the establishment of river basin authorities that are empowered to take the necessary actions.

**Energy**: Malaysia's primary commercial energy supply consists of four fuels namely oil, gas, coal, and hydroelectricity. The current supply mix is heavily dependent on fossil fuels, with less than 5% contribution from hydroelectricity in year 2010 and negligible share from non-hydroelectric renewables. The nation's electricity generation mix is largely driven by fossil fuels particularly coal, and it is noteworthy that there is no share of renewables reported in 2010 or projected to 2030. Instead, nuclear energy has been planned for deployment.

Added to that, second-generation bioethanol derived from non-food biomass sources especially empty fruit bunches from oil palm waste holds potential for petrol blending for use as transportation fuel. First-generation ethanol became environmentally notorious because it was made from corn and other food crops, thereby creating competition and conflict with food production. Second-generation ethanol is made from non-food biomass which is theoretically cheaper and more plentiful but the technology needs to be made workable no matter what the theory may be.

Another potential source of energy is microalgae which can thrive on waste water such as Palm Oil Mill Effluent (POME) and is more productive of biomass than land plants. The lipids from algal biomass can be converted to biodiesel and bioethanol for energy. An integrated system can be developed to simultaneously harness energy from recovering the biogas of methane from microalgae biomass residue and in POME treatment.

Other sources of energy include methane that could be generated from suitably engineered sanitary landfills, electricity from mini hydropower stations, solar energy captured by solar panels, and nuclear energy using thorium-based technology. The challenge is to achieve economic viability within a feasible timeline.

**Waste**: Waste management in Malaysia is relatively primitive, with two main options: disposal in landfills and incineration. It is estimated that 90-95% of municipal solid waste ends up in landfills. There is high public resistance to incineration plants located close to populated areas. If they are located far away the cost of trucking the waste rises greatly. The amount of waste will increase with the increase in population, which, according to the Department of Statistics Malaysia, will rise from to present 28.6 million to 36.4 million in 2030.

The concept of waste as a resource worth recycling is only realised in the case of old newsprint and paper. The key to recycling and reuse of household waste is separation of waste into manageable components at source. Paper is effectively recycled because there are pulp and paper plants that use waste paper and they pay for the collection of paper by collectors who provide a house-to-house service. The success of paper recycling indicates that glass, metals, plastic and other recyclable products could be similarly treated. Manufacturers of glass and metal products might be taxed for pollution if they have no programmes for collecting and recycling their products.

Moreover, manufacturers should also be encouraged to design products with longer life spans, and that can be easily separated into components for recycling. All kinds of green and food waste can be composted to make fertilisers. With planning and sustained implementation, the amount of waste needing incineration and burial can be reduced to a small fraction of current waste. In many developed countries, Composting Councils or similar bodies have been set up by local authorities to promote comprehensive, integrated and sustained efforts in waste management. The local conditions are different from each place. Therefore, local bodies should be better at devising solutions. For example the disposal of waste paper may depend on whether there is a local paper industry and if not, is it possible to establish a viable local alternative?

Apart from that, POME and attached-to-mill landfills are still environmental problems. Standards for POME discharged in Peninsula Malaysia are still not good enough according to new environmental requirements and as compared to Sabah and Sarawak. The composting of waste biomass using innovative zero discharge technologies to make nutrient-rich composts also deserves more effort in Research and Development (R&D). There is high demand for fertilisers in agriculture which could be met by the development of an intensive industry to manufacture high-quality organic fertilisers.

The rise of the chicken industry has resulted in immense quantities of chicken dung that need to be properly composted. Existing efforts to convert chicken dung into organic fertilisers are unsatisfactory; the products are of poor quality and could even be toxic. The chicken industry should be held accountable for the safe disposal of chicken waste.

**Land and forests**: One of the most scenic drives in Malaysia is the drive from Gombak up to the mountain pass between Selangor and Pahang. Only a short distance out of Kuala Lumpur, splendid tropical high forests stretch all the way from the roadsides to the mountain crests, but only on the Selangor side of the pass. On the other side is Pahang, with almost no scenic forests to be seen. This is a stark reminder that land and forests are administered by the States and different States have had different priorities.

The area of forests in Malaysia now stands at slightly above 50% of the land area and the overall figure has been relatively stable for the past 10 years. This is good news. However, the bad news is that the amount of timber taken out of forests has been excessive, exceeding the "allowable annual cut" to sustain good natural regeneration, i.e. the ability of the forest to regrow without human assistance. The amount of timber that second and third generation forests can carry is expected to be significantly below the original amount. Intervention is needed to promote regeneration in the worst affected areas and accelerated R&D is needed to reduce logging damage.

The importance of forests for the maintenance of the global climate, biodiversity and other environmental resources has led to the realisation that the policy of automatically giving priority in allocation of land to mining and agriculture should be replaced by a freeze on further forest clearance. The growth of agriculture should be based on more efficient use of the land already cleared for agriculture instead of on the clearing of more forests. There is a special need to intensify forest regeneration and to place all the remaining mangrove forests under strict forest management.

Malaysia is a mega-diversecountry, ranked 12$^{th}$ in the world ranking of countries. In 1992 the National Forest Policy was broadened to include the conservation of biological diversity, the sustainable utilisation of forest genetic resources, and the role of local communities in forest development. However, research by government research institutions and government-salaried scientists is too slow and expensive to cover the rich biodiversity resources of the country. The potential of Malaysia's biodiversity wealth can only be realised by harnessing the interest of amateur natural historians, and through the formation of a Natural History Museum to serve as the national centre and mentor for all biodiversity research. Furthermore, Malaysia is placing increased emphasis on the role of forests in recreation and nature tourism. The area of land protected as national parks amounts to 434,340 ha in Peninsular Malaysia, 245,172 ha in Sabah and 78,177 ha in Sarawak. In nature tourism, Sabah is considered the most advanced of the States of Malaysia and provides a good role model for other States.

**Science, Technology and Innovation for the environment**: The environment offers innumerable opportunities for science, technology and innovation. Chapter 7 provides a review of efforts in Malaysia and elsewhere to promote innovation. Most top-down models for innovation based on government planning have not worked as hoped, but new models are being tried and it important to keep trying. Special problems faced in Malaysia include absence of competition and urgency in research, low expectations, inadequate promotion of innovation, and a poor DIY culture. These are problems that need to be addressed by those who are in a position to influence the research culture of the country, particularly in the universities and research institutes.

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## ACRONYMS

ASM — Academy of Sciences Malaysia
BCM — Billion Cubic Metres
BMP — Best Management Practices
BO — Business Opportunities
BOD — Biochemical Oxygen Demand
CDM — Clean Development Mechanism
CFC — Chlorofluorocarbons
CTI — Coral Triangle Initiative
DDT —
DID — Department of Irrigation and Drainage
DMA — District Metering Areas
EEZ — Exclusive Economic Zone
EGS — Environmental Goods and Services
E&E — Electronics and Electrical
EP — Entry Project
EPP — Entry Point Project
ETP — Economic Transformation Programme
GCM — Global Circulation Models
GDP — Gross Domestic Product
GHG — Green House Gas
GIS — Geographic Information System
GNI — Gross National Income
GTP — Government Transformation Programme
HTC — Humid Tropic Centre
ILBM — Integrated Lake Basin Management
ICZM — Integrated Coastal Zone Management
IPR — Intellectual property rights
ISMP — Integrated Shoreline Management Plan
IRBM — Integrated River Basin Management
IUWM — Integrated Urban Water Management
IWK — Indah Water Konsortium Sdn Bhd
IWRM — Integrated Water Resources Management
KeTTHA — Ministry of Energy, Green Technology a nd Water (Kementerian Tenaga, Teknologi Hijau Dan Air)
KPKT — Ministry of Urban Well-being, Housing and Local Government (Kementerian Kesejahteraan Bandar, Perumahan dan Kerajaan Tempatan)
LUAS — Lembaga Urus Air Selangor
MADA — Muda Agricultural Development

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| | | Authority |
| MBJB | — | Majlis Bandaraya Johor Bahru |
| MICE | — | Meetings, Incentives, Conference and Exhibition |
| ICAO | — | International Civil Aviation Organisation |
| ICT | — | Information and Communication Technology |
| IMO | — | International Maritime Organisation |
| IoV | — | Internet of Vehicles |
| IPR | — | Indirect Potable Reuse |
| iRAP | — | International Road Assessment Programme |
| IRTAD | — | International Traffic Safety Data and Analysis Group |
| ISO | — | International Standards Organisation |
| ITIS | — | Integrated Transport Information System |
| ITS | — | Intelligent Transportation System |
| IWTS | — | Inland Waterway Transportation Systems |
| KeTTHA | — | Kementerian Tenaga, Teknologi Hijau dan Air |
| KLIA | — | Kuala Lumpur International Airport |
| KLIA2 | — | Kuala Lumpur International Airport 2 |
| KTMB | — | Keretapi Tanah Melayu Berhad |
| LFA | — | Logical Framework Analysis |
| LiDAR | — | Light and Radar |
| LNG | — | Liquefied Natural Gas |
| LSE | — | Labuan Shipyard and Engineering Sdn Bhd. |
| LP | — | Local Plan |
| LPG | — | Liquefied Petroleum Gas |
| LPT | — | Land Public Transport |
| LRT | — | Light Railway Transit |
| MAE | — | MAS Aerospace Engineering |
| MAHB | — | Malaysia Airports Holding Berhad |
| MAS | — | Military Aerospace Sector |
| MHA | — | Malaysian Highway Authority |
| MIGHT | — | Malaysian Industry – Government Group for High Technology |
| MIROS | — | Malaysian Institute of Road Safety Research |
| MLFF | — | Multilane Free Flow |
| MITRANS | — | Malaysian Institute of Transport |
| MOT | — | Ministry of Transport |
| MoU | — | Memorandum of Understanding |
| MRO | — | Maintenance, Repair and Overhaul |
| MSMA | — | Manual Saliran Mesra Alam |
| MyVAP | — | Malaysian Vehicle Assessment Programme |
| NASA | — | National Aeronautics and Space Administration |
| NCAP | — | New Car Assessment Programme |
| NCER | — | Northern Corridor Economic Region |
| NFI | — | National Foresight Institute |
| NKEA | — | National Key Economic Areas |
| NLPTM | — | National Land Public Transport Master Plan |
| NRF | — | National Research Foundation |
| NSA | — | National Safety Authorities |
| OEM | — | Original Equipment Manufacturer |
| ORT | — | Open Road Tolling |
| PEMANDU | — | Performance Management and Delivery Unit |
| PMR | — | Pressure Management Areas |
| PRC | — | People’s Republic of China |
| POME | — | Palm Oil Mill Effluent |
| PUSPAKOM | — | Pusat Pemeriksaan Kenderaan Berkomputer (Computerised Vehicle Inspection Centre) |
| PVT | — | Periodic Vehicle Testing |
| PWD | — | Public Works Department |
| RMP | — | Royal Malaysian Police (Polis Diraja Malaysia) |
| R&D | — | Research and Development |
| RSA | — | Road Safety Audit |
| RSD | — | Road Safety Department (Jabatan Keselamatan Jalan Raya) |
| RTD | — | Road Transport Department (Jabatan Pengangkutan Jalan) |
| SAP | — | Special Area Plan |
| SCORE Energy | — | Sarawak Corridor of Renewable |
| SDC | — | Sabah Development Corridor |
| SEA | — | South East Asia |
| SMART | — | Stormwater Management and Road Tunnel |
| SMS | — | Safety Management System |
| SP | — | Structure Plan |
| SPAD | — | Suruhanjaya Pengangkutan Awam Darat (Land Public Transport Commission of Malaysia) |

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|---|---|---|
| SRI | — | Strategic Reform Initiatives |
| SS | — | Suspended Solids |
| S&T | — | Science, Engineering and Technology |
| STI | — | Science, Technology and Innovation |
| TDMA | — | Time Division Multiple Access |
| TfL | — | Transport for London |
| TOD | — | Transit Oriented Development |
| TRB | — | Transportation Research Board |
| TRG | — | Transportation Research Group |
| UAV | — | Unmanned Aerial Vehicle |
| UK | — | United Kingdom |
| UMPEDAC | — | UM Power Energy Dedicated Advanced Centre |
| UN | — | United Nations |
| UNDP | — | United Nations Development Programme |
| UNEP | — | United Nations Environment Programme |
| UNESCAP | — | United Nations Economic and Social Commission for Asia and the Pacific |
| UPM | — | Universiti Putra Malaysia |
| UPT | — | Urban Public Transport |
| VTS | — | Vessel Traffic Service |
| WHO | — | World Health Organisation |
| WIPO | — | World Intellectual Property Organisation |
| WP | — | Wilayah Persekutuan (Federal Territory) |
| WSUD | — | Water Sensitive Urban Design |

# CHAPTER 1
## INTRODUCTION

The aim of this Mega science study is to provide an overview of environmental issues and to promote the search for innovative solutions.This study covers five environmental sectors, namely carbon/climate, water, energy, waste and land/forests. Separate Ministries of government departments are responsible for the separate sectors and each sector is backed by professionals with specialist interests. Division into sectors has had the advantage making management simpler.The downside is that each sector has promoted its own interests. In reality, all the sectors are linked, and the biggest challenge in environment management now is to understand the linkages in order to deal effectively with the environmental challenges of the future. Departments, ministries and specialist professionals have to learn to work together to support new solutions, transcending the narrow sectoral concerns of the past.

### 1.1 BACKGROUND

As time progression, environmental issues are highlighted in the media. The news may be aboutdrought, bush fires and water shortages, followed by tropical storms and flooding,followedby landslides, garbage overflow, disease outbreaks, and so on, without end. Firefighting is the usual reaction by harassed authorities. Notwithstanding, emergency solutions devised in a hurry are usually not as sustainable as solutions based on holistic knowledge and implemented in a preplanned manner. To arrive at holistic solutions and to implement them in the absence of emergency, we need public officials who understand the environment in totality, and a general public that is well-informed and supportive. Thus, we hope this study will help to promote a better understanding of the environment among public officials as well as the public. Thereby, contributing to better environmental management.

This study omits consideration of the ocean, which needs a separate study because the ocean (divided into several 'oceans', but all are interlinked and vastly larger than the total land area) is being depleted by over-fishing, pollution from waste and most ominously, by increase in acidity. The increase in acidity is due to carbon dioxide passing into the ocean from the atmosphere.

## 1.2 ENVIRONMENTAL ISSUES

Environmental issues are complex. However, at present solvable, although some may think otherwise. It is feared that the longer we postpone, the more difficult the solutions will be. Hence, the following offers a panoramic view of the environment, with a time horizon stretching up to 2050.

### *Ownership of the Environment*

Management of the environment is tied up with ownership of the resources associated with the environment. In the past, when populations were small, land could be utilised for farming, housing or mining by anyone who had the means to clear and use the land, and when the land was abandoned it reverted to forest and could be reused by others.

The idea that land is a permanent property of the State and that the state may then issue grants of ownership to individuals and corporations for fixed periods or in perpetuity, was implemented by the British Administration as a means of obtaining state revenue. With ownership of land came ownership of forests and other products of the land, the minerals in the land, and the water resources on or under the surface of the land. When Malaysia came into existence as a Federal country, land and its associated resources became the property of the individual states. Offshore resources, such as petroleum resources, belong to the Federal Government if they fall under the territory of Malaysia. Nonetheless, oceanic resources not within national boundaries have been open to free exploitation but this situation is now gradually being brought under control by international conventions. Malaysia has so far not been active in the exploitation of oceanic resources.

Under the UN Convention on Biodiversity that came into force in 1993, the biodiversity resources within a country are the property and responsibility of the countries in which they occur. However, the atmosphere remains global common propertyandthere are no mechanisms of governance in place. Furthermore, now, with the threat of global warming, a rising ocean level, and acidification of the ocean, all due to man-made changes in the atmosphere, the matter of management of the atmosphere has become increasingly urgent. What the world needs is a new global understanding of collective ownership and responsibility for the environment, like a new layer of ownership on top of existing layers. At present, different nations have different priorities. There is a danger that such differences will make it impossible for the world to react to environmental threats in a collective, timely and effective manner even in the face of impending disaster.

### *Technological Innovation as a Principal Driver of Change in the Modern World*

The massive and rapid changes to the environment that have occurred since the Industrial Revolution that began in the 1700s (c. 1760) were the result of STI. Normally, human societies are resistant to change, but scientific innovation has turned out to be a culturally neutral force that can break through all the normal barriers. For instance, electric street lighting began with the efforts of one innovator and entrepreneur, Thomas Edison (1847 – 1931), who invented the electric light bulb and staged a demonstration of electric street lighting in 1879. Before Edison died in 1931, electric street lighting had become a reality in cities in many parts of the world. The motorcar, aircraft and other technological innovations have also had histories of rapid global acceptance. In addition, recent examples include iPads, cellular phones, thumb drives, digital cameras and high-speed trains. Self-driving cars are already in the pilot testing stage. Overall, the pace of innovation is accelerating steeply and there is no turning back.

Until about 50 years ago, few people thought that the environment needed to be protected, saved or managed. The dominant concept in ecology was that disturbances were small compared to the enormity of the global environment, and nature would always be able restore the original equilibrium.

The invention of DDT as a cheap and effective poison to wipe out mosquitoes and other dangerous insects was hailed as a miracle. However, the euphoria was short-lived and mosquitoes made a comeback. DDT also turned out to be an indiscriminate insect-killer with a long active life. As a result, birds and other animals that ate insects were poisoned. The poison had found its way into the food chain so that food supplies became more and more tainted. As it turned out, DDT was just the beginning of the problem of man-made chemicals in the environment, sprayed on to fruits and vegetables and fed to farm animals to control pests and diseases, but eventually threatening the health of humans. Today, the safety of food and water has become a pervasive public issue due to the increasing amounts of synthetic chemical products in the environment in the form of pesticides, drugs, plastics and industrial chemicals, the possible long-term effects of which are not yet known.

In the 1970s and 1980s it was found that the ozone layer in the stratosphere that absorbs up to 97% of incoming ultraviolet light was being damaged by chlorofluorocarbons (compounds of chlorine and fluorine with carbon) used in refrigeration and aerosol sprays. The dramatic appearance and annual enlargement of the 'ozone hole' in the stratosphere caused sufficient global concern to prod all countries to collectively phase out the use of Chlorofluorocarbons (CFCs). This was brought into effect through the Montreal Protocol. As a result of implementation of the Montreal Protocol, the ozone layer is gradually recovering from damage. With further action to phase out hydroflourocarbons, used as a less-damaging substitute for CFCs, by 2030, the ozone layer is expected to be restored to 1980 levels by 2050. The success of this Montreal protocol has been hailed as a good model for future international action to protect the global environment

In the 1980s scientists began to be aware that world temperatures were rising and the rise seemed to be due to a phenomenon known as the greenhouse effect, caused by the increase in concentration of certain gases, especially carbon dioxide, methane and nitrous oxide in the atmosphere. The greatest culprit is carbon dioxide. Carbon dioxide is produced when the so-called 'fossil fuels' such as coal and petroleum are burnt (combusted).

Coal is nowadays mainly used to generate electricity, and petroleum is used as a portable fuel to power all forms of transportation (ocean, air and land transport). In the past few decades, a massive and growing stream of carbon dioxide has been sent into the atmosphere by the combustion of fossil fuels. At the same time, the clearing of forests and the intensification of agriculture have resulted in carbon stores in forests and soils being converted to carbon dioxide. Through the greenhouse effect, the average world temperature has risen 1°C compared to before the Industrial Revolution and a rise by 2°C is now considered inevitable (World Development Report of the World Bank 2010).

This increase may seem small when compared with daily and seasonal fluctuations in climates, but this is an increase over and above the normal range of fluctuations, and on a global scale it is expected to have catastrophic effects. The increase in global temperature is already evident in the thinning of ice at the poles and the early melting of snow on the tops of high mountains, leading to a rise in global sea levels and changes in the flow of water in the great rivers that are fed by snow in the Himalayas, Tibet and other high mountain regions. The increase in temperature is also responsible for increasing the amount of water evaporated into the atmosphere, causing unprecedented changes in rainfall and wind patterns.

Globally, there is little agreement between countries on how to share out the task of reducing global fossil fuel usage, except for the European Union, which has set a target for 20% of its energy to come from renewable sources of energy by 2020, half of it to be implemented by substitution with renewable sources and half from savings through greater efficiency in energy usage. Under its *Renewable Energy Directive,* member states of the European Union have taken on binding national targets for raising their share of renewable energy in their energy consumption by 2020.

These targets, which reflect Member States' different starting points and potential for increasing renewables production, range from 10% for Malta to 49% for Sweden. These national targets will enable the European Union (EU) as a whole to reach its 20% renewable energy target for 2020, which is more than double the 2010 level of 9.8%. In setting such a target, whole new suites of innovation opportunities are created, ranging from the harnessing of wind, solar, hydro and tidal power to the plantation of trees for renewable biomass energy, the redesign of motor vehicles, redesign of buildings, recovery of energy from waste, invention of new and powerful batteries to store energy,and so on.

The targets will reduce the EU's dependence on imported energy. However, the implementation of the targets has been complicated and difficult for a mixture of reasons ("Europe's Energy Woes", *The Economist*, January 25, 2014). Nevertheless, Europe has raised the target to 40% reduction by 2030. Countries that do not set energy targets and stimulate innovative means to meet such targets may miss out and be left behind by the new innovations that will reshape the economy of the world.

### *The Effect of Science, Technology and Innovation on the Malaysian Environment*

In Malaysia, up to the 1950s, most of the population was rural. Firewood was the main fuel for cooking and every rural household kept a pile of rubber wood as fuel. Ground water, drawn up with buckets from shallow wells, was the most common source of water for domestic use. Kerosene was an essential commodity for lighting and was sold in every village sundry shop in tin cans and bottles. The open drains emptied waste straight into the rivers. The most common form of transportation was the bicycle. The population of Malaysia was 6.1million.

Yet, new technologies had already been innovated and incubated, mainly in the USA, and were ready for implementation on a global scale. By the year 2000, within a short span of 50 years, electricity, produced by hydroelectric and coal-fired generators and distributed by a national grid of wires, was providing lighting for nearly every household, even in remote areas. Firewood,as a source of heat for cooking,had been replaced by gas from the petroleum industry or by electricity, whereas, water was supplied by networks of pipes that connected State-managed reservoirs to individual households. Cars then had become the main form of transportation. In addition, computers had become common and were changing the nature and organisation of work.

In the same period of 50 years, the population of Malaysia almost quadrupled to 23.4 million (up from 6.1m in 1950) and that of the world more than doubled to 6 billion (from 2.5 billion in 1950). This vast increase in population was made possible by technological improvements in public health and in food production and distribution. At the same time, the human population has become concentrated in cities. The concentration of people in the cities has created huge localised demands for energy and water and huge localised amounts of waste to be disposed of safely. However, it is still common for sewage in Malaysia to drain into the rivers and the rapidly expanding oil palm industry is generating more waste than natural restoration processes can handle. As a consequence, many rivers are heavily polluted.

### *The Decoupling of Science, Technology and Innovation from Detrimental Environmental Effects*

STI has transformed the world by providing the tools to reduce poverty and raise life expectancy. These improvements have come at a cost of much damage to the environment. There is reason to think that improvements can be made without damage to the environment; that the two are not necessarily coupled in a cause-and-effect relationship. STI, properly channelled, may even contribute solutions to undo the collateral damage that has been caused. It may be possible to eradicate poverty, provide and maintain a good standard of living, avert disastrous climate change, keep rivers and oceans healthy, protect scenic landscapes and provide room for all the forms of life that share the earth with humans. This may seem like a tall order, but it is worth aiming for.

### *The Role of Government*

The Government is responsible for most of the big decisions involving the environment. It is responsible for public utilities such as the supply of electricity, water and public transportation, the disposal of waste, and the management of forests, water bodies and fossil carbon resources. It is also responsible for the atmosphere. Governments can affect the use and misuse of resources through the selective application of subsidies and tariffs. It could set targets and standards for achieving desirable outcomes, and devise incentives for compliance, In innovation, Governments can provide public recognition for innovators and make funds available for research and development. It can monitor and disseminate information on the State of the environment so that would-innovators can have access to accurate national base-line data. It could fund the establishment of pilot projects.

Governments are rarely monolithic. In a Federal system, the powers of the Government could be exercised at Federal, State or local levels. In many significant ways, local authorities can be more proactive than the State or Federal Authorities. In Australia, for example, Sydney has become the first city to become carbon-neutral.Townships and local communities may take steps to manage their environment and provide models for others. Competition between local authorities may result in more innovation. Differences in local environments may require local adaptations.

As consequence, the agencies of Government, such as Government Ministries and Departments and Public-funded Institutes and Universities could promote good environmental practices such as waste separation, reduction of energy usage (reduction of carbon footprint), tree-planting and so on, and publicise their environmental contributions in their annual reports.

### *The Role of Society, Collectively And Individually*

Since the environment is impacted by the daily actions of every individual, in the way individuals use environmental resources and generate waste, individuals can contribute to the collective effort by making their own contributions regardless of what governments do. This would involve a change in individual habits and attitudes in the use of energy, water and land and in the generation and disposal of waste. The habits of mass-consumerism which have based the mass-production and consumption of throwaway goods, have so far been subsidised by the public due to the cost of waste management has not been factored into the cost of production. Manufacturers should now strive to make goods more lasting, more biodegradable, or easier to disassemble for recycling.

Hence, the changes will require strong public understanding and support. This is as environmental issues require long term vision and commitment to resolve. For that matter, corporate and individual support for environmental education, research and innovation can make a crucial difference, whereas in the past, development could be pursued without limits, the next few decades will require hard decisions to be made nationally and globally, and these decisions will need to be implemented across all parts of society. In short, where environment is concerned, nobody can escape the consequences of ignorance and inaction.

# CHAPTER 2
## CARBON AND CLIMATE

The dominant global environmental issue of today is climate change, in particular, global warming resulting from a steep increase in carbon dioxide in the atmosphere from the combustion of coal and hydrocarbons. The concentration of carbon dioxide is now over 392 ppm as compared to 280 ppm in pre-industrial times or before 1850 (see e.g. Robert Kunzig in National Geographic News; May 9 2013).

### 2.2 CARBON AND CLIMATE

Most of the additional amount has been added in the past few decades and 85% of it has been contributed by the burning of coal and hydrocarbons. The earth is heated up by solar radiation and in turn the earth radiates heat into outer space. Carbon dioxide and other greenhouse gases retard the radiation of heat out of the earth in what has been called the "greenhouse effect"; after the way greenhouses made of glass trap solar energy and become hotter inside than outside. We experience a personal example of the greenhouse effect when we park our cars in the sun and the temperature inside the car gets higher than the temperature outside. The greenhouse effect prevents the earth from losing too much heat, otherwise the whole earth would get frozen and inhospitable at night. The problem is that there is a fine thin line of balance between incoming and outgoing heat, and this balance is being upset by the recent unprecedented increase in carbon dioxide.

Carbon dioxide in the atmosphere is part of the total carbon on earth. The total amount of carbon on earth is fixed. If the amount of carbon in the atmosphere is increased, the increase must be the result of transfer into the atmospheric pool from one or more of the other carbon pools on earth. Carbon is present not only as carbon dioxide in the atmosphere but also in various forms in living organisms, forests, soil, oceans, coal deposits, petroleum deposits, etc. (**Table 1**). This chapter begins with the nature of carbon pools and how carbon is transferred between them. The unit of measure for describing global carbon pools is the gigatonne (Gt). One gigatonne is 1billion tonnes. One tonne is 1000 kg.

Table 2.1 Summary Of Major Carbon Pools in Gigatonne* (1 Gt = 1 Billion Tonnes)

| Carbon pools | Amount C in Gt |
|---|---|
| Atmosphere | 750 |
| Vegetation (land and ocean) | 610 |
| Soil (to 1 m deep) | 1500 |
| Coal deposits | 900 |
| Hydrocarbon fossil deposits | 4,000 |
| Methane hydrate | 500 – 5,000 |
| Ocean water | 38,000 |
| Rocks in earth's crust | 100,000,000 |

Sources: globecarboncycle.unh.edu/CarbonPoolsFluxes.shtml, worldoceanreview.com/en/wor-1/energy/methane-hydrate/

Note: The values cited are estimates that vary between authorities and are modified as research continues.

## 2.3 FORMS OF CARBON

Carbon is one of 98 naturally-occurring chemical elements on earth. In chemical notation, carbon is designated by the letter C. The unit carbon atom is unstable and practically unknown as a free atom. Nonetheless, it becomes very stable when the carbon atoms are bonded to each other in various configurations.

There are three well-known configurations, which result in diamond, graphite and coal. Namely, diamonds are the hardest of all naturally-occurring substances while graphite is so soft that it makes a black streak when pressed on a piece of paper. Polished diamonds are highly prized as gemstones but industrial-grade diamonds are used as abrasives. Graphite is the 'lead' of everyday pencils, so called because it was thought originally to be a form of lead, but lead is an entirely different element. Coal is the fossilised wood of trees buried and subjected to extreme heat and pressure through geological time. In the process of fossilisation nearly all other elements in wood are removed leaving amorphous carbon. Charcoal is coal made by incomplete burning of wood.

The scientific understanding of carbon began in 1772 when Antoine Lavoisier showed that coal and diamond could both be burnt and in burning, produce the same amount of gas (carbon dioxide) per gram. In 1786, Gaspari Monge and CA Vandemonde did the same kind of experiment with graphite and showed that graphite is elementally the same as coal and diamond. Carbon was formally designated as an element in a book by Lavoisier in 1789.

Elements can be bonded with other elements in different ways to form different compounds. Over ten million different compounds of carbon are known and, amazingly, these represent only a small fraction of what is theoretically possible. Carbon dioxide $CO_2$ is carbon bonded with oxygen (one C to two O atoms). At the other extreme are fibres such as those in cotton and wood, made up of very long chains of C combined with other elements.

## 2.3 CARBON IN THE ATMOSPHERE

The carbon pool in the atmosphere is a relatively small pool holding 750 Gt of carbon mostly as carbon dioxide, with smaller amounts of methane $CH_4$. As the atmospheric carbon pool is small compared to other pools, it is relatively easy to change by transfer from other pools. Before the onset of modern of fossil fuel usage and forest-clearing, the level was about 560 Gt;hence, making it the smallest of all the pools. It has now overtaken the vegetation pool, which has declined to 610 Gt. The atmospheric $CO_2$ level has been rising at 2.0 ppm per annum from 2000 to 2009 and the rate has increased since then.

### *The Vegetation Carbon Pool*

The vegetation carbon pool is the main component of the living carbon pool. A living organism is a body made of carbon-based materials, kept alive by energy from carbon-based fuels. Living organisms include plants, animals, fungi and microbes. The mass of bodies of all living thing is collectively known as biomass. The carbon content of oven-dry plant biomass is 45 – 50%. The carbon content of animal biomass is lower, at about 18%. The carbon pool of living vegetation is estimated to be about 610 Gt of which 560 Gt are in land plants, mostly in the form of wood. The rest is in ocean plants, mostly as plant plankton.

Energy is required by living organisms to stay alive,grow, move, and reproduce. The ultimate source of energy for living organisms isthe sun, in particular the part of the solar light spectrum that is captured by green plants in the process of photosynthesis. Land plants take in carbon dioxide from the atmosphere while water plants take in carbon dioxide dissolved in water. In the plant, the carbon dioxide is reacted with water ($H_2O$) to form glucose $C_6H_{12}O_6$. The captured energy of the sun is then stored in the glucose molecule. Simultaneously, oxygen $O_2$ is released. The process of photosynthesis is summarised in the formula: $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$. Photosynthesis takes place in chlorophyll-containing organelles known as chloroplasts, in chemical steps mediated by enzymes. Enzymes are molecules that enable chemical reactions to take place at normal body temperatures.

The energy stored in glucose $C_6H_{12}O_6$ becomes available to living organisms through the process of respiration, which is the reverse of photosynthesis: $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$. Oxygen is taken in from the atmosphere (or from solution in water) and reacted with glucose in chemical steps mediated by enzymes. Carbon dioxide and water are produced and energy is made available to the body in finely regulated amounts, in a form that the organism can use.

In the plant, glucose is also the starting material for the synthesis of cellulose, which is the building material for plant cell walls, fibres and wood. Plants produce more glucose than they need for structural building and energy. The extra is processed, through the action of enzymes, into sugar, starch or fats. It is combined with nitrogen, sulphur and phosphorous (obtained from nutrients in the soil) to form the proteins, DNA, ATP and other compounds essential for life. Stored plant products include sugar (e.g. in sugar cane), starch (e.g. in tapioca), fats (e.g. in oil palm) and protein (e.g. in soy bean).

Animals feed also directly on plants or indirectly by feeding on other animals to obtain the carbohydrates, fats and proteins that they need for body building and for energy. Fungi, now classified independently of plants and animals, live on plants and animals, as parasites on living tissues or saprophytes on newly dead tissues. Through respiration, all living organisms return carbon dioxide to the atmosphere.

Hence, there is continuous exchange of carbon between living organisms and the atmosphere, with 120 Gt of carbon taken in annually by land plants in photosynthesis, balanced by the same amount of carbon returned to the atmosphere via respiration by all living terrestrial organisms collectively. In the ocean there is a similar exchange of carbon dioxide between ocean organisms and water.

Biomass can be burnt or combusted and in the process, water is driven off as steam and the carbon is reacted with oxygen from the atmosphere to form carbon dioxide. The energy released by combustion is high-temperature heat, which is hot enough to kill all forms of life. In contrast, the energy to sustain life comes from metabolic processes within living organisms that take place at normal body temperatures, in a series of finely regulated small steps mediated by enzymes.

### *The Soil Carbon Pool*

The soil contains carbon contributed by the remains of dead biomass such as leaf litter and dead roots in various stages of decomposition. The carbohydrates, proteins and fats in recently dead biomass are sources of food for insects, bacteria, fungi, and other organisms that live in the soil and decompose biomass.

Among the results of biological decomposition of biomass is the formation of humus. Humus improves the texture and fertility of soils and decomposes at a very slow rate. Eventually even humus is decomposed, to carbon dioxide, water and soil nutrients. Soil may also contain 'recalcitrant' carbon in the form of charcoal from wild fires or open burning. Charcoal is said to be recalcitrant because it is an elemental form of carbon that cannot be easily changed except by fire which would change the carbon to carbon dioxide. The humus and charcoal particles (if present) are responsible for the dark colour of the top layer of undisturbed soils. Together with soil microbes they are also believed to be responsible for concentrating nutrients in the top layer of undisturbed soils

Globally, the soil carbon pool is estimated at 1,500 Gt. In forests, the amount of carbon in the soil usually exceeds the amount of carbon in the living vegetation except in the humid tropics, in which dry land forest (as opposed to wetland forest) contain more C above than below ground. When a forest is cleared, the loss of leaf litter exposes the soil to higher temperatures and to forces of erosion (such as rain splash), this results in its humus content becoming quickly decomposed to carbon dioxide, as well as destroying its microbial content. Consequently, this has several negative impacts. Namely, carbon dioxide is added to the atmosphere. The destruction of nutrient-rich soil microbial biomass allows its nutrients to be lost by leaching, and the soil is physically degraded. A good soil is permeable to water and air and able to retain moisture and nutrients. In clayey soils that tend to get compacted and impermeable, humus prevents compaction and improves permeability. In sandy soils that are poor in water and nutrient retention, humus improves water and nutrient retention. In the process of losing its high-carbon humus content, soil is rendered less able to support plant growth without massive use of fertilisers and other inputs.

### *The Oceanic Carbon Pool*

The ocean carbon pool is much bigger than the atmosphere and vegetation pools. It holds 38,000 Gt of carbon, mostly in the form of dissolved $CO_2$ and dissolved carbonates such as calcium carbonate $CaCO_3$. At the surface of the ocean there is continuous interchange of $CO_2$ between the surface water and the atmosphere, but in the ocean depths, the pool of dissolved carbon is almost undisturbed.

### *Acidification of the Ocean*

The increase in $CO_2$ concentration in the atmosphere has the parallel effect of increasing the concentration of $CO_2$ in the ocean because $CO_2$ is exchanged between the atmosphere and the ocean. It is estimated that 30-40% of $CO_2$ generated by human activities goes into the ocean. As a result, the warming of the atmosphere is accompanied by the acidification of the ocean because dissolved $CO_2$ has acidic properties. The increase in ocean acidity has deleterious effects on marine life. A decline of coral formations has already been detected.

The expected results on planktonic life forms will affect the marine food chains, damage the productivity of oceanic fisheries and endanger human food security. A recent article in The Economist (Jan 18, 2014) has drawn attention to the work of E. Sandford and his team in the University of California, Davis, comparing the growth of oysters in normal seawater and in water containing double the normal level of dissolved $CO_2$, which is the expected level in the oceans in 2100. The size of the oysters was reduced by 30-40%.

### *The Fossil Carbon Pool: Coal and Hydrocarbons*

Over a geological time span of hundreds of millions of years, layers of biomass have been accumulated in low-lying areas or water basins and buried under soil and sand, which has stopped the process of biological decomposition. These deposits have, through high pressure and heat, been fossilised into coal or converted into hydrocarbons. The total of coal deposits are estimated to be 900 Gt, while hydrocarbon deposits may be as much as 4,000 Gt. In short, the fossil carbon pool is larger than the atmospheric, vegetation and soil carbon pools combined, but all of it originates from the living carbon pool of ancient times.

Therefore, all coals and hydrocarbons can be used as fuel in combustion. In combustion, carbon dioxide is produced. As it has taken many millions of years to make coal and hydrocarbon deposits from fossil biomass, these fuels are regarded as non-renewable. In contrast, recent biomass is considered a renewable form of fuel because vegetation can be grown readily within the human time frame.

### *Coal*

There are coal deposits in all continents except Antarctica. Many coal deposits began as wetland forests during the Carboniferous Period 300 – 350 million years ago. The wetland conditions in those forests slowed down the processes of decay, allowing biomass to accumulate as peat. Soil was slowly deposited over the peat and through geological time, massive deposits of biomass were accumulated under thousands of meters of soil (silt, sand and clay) and subjected to high temperatures and pressures. In the process the buried biomass was changed into coal, which is almost pure carbon.

Coal is nowadays the main fuel for the generation of electricity. In generating electricity, coal is fired or combusted to change water to steam. Steam expands into a very much larger volume than water. The expanding steam is channelled to spin turbines that generate electricity. About 40% of the world's supply of electricity is generated from coal. Coincidentaly, in Malaysia the supply of electricity generated from coal is about 40%, and this level is expected to be maintained until 2030 (**Table 4**). China is the world's largest producer and consumer of coal, relying on coal for 70% if its energy requirement.

### *Hydrocarbons*

Hydrocarbons are compounds of carbon bonded to hydrogen, derived from the biomass of marine plants and animals accumulated in the sea bottom, covered by soil sediments and subjected to intense heat and pressure over geological time. Under high pressure and heat, the sand and other materials in soil have fused into rock formations. Over the ages, such areas may have been alternately raised above water and then submerged again. With each submersion, another layer of marine organisms would be deposited. These alternate risings and submersions over millions of years have resulted in gas and liquid petroleum deposits at various depths in the same drilling area.

### *Petroleum*

Petroleum is a mixture of liquid hydrocarbons ranging from transparent free-flowing liquids to dense black tar. Highly liquid petroleum is used a fuel, to generate electricity and in internal combustion engines to power motorised vehicles. The densest formof petroleum, which is known as bitumen, is used to surface roads. Petroleum is also the starting material for the manufacture of plastics. Whether used as a fuel to generate electricity or to power motorised vehicles, the products of petroleum combustion are carbon dioxide and water.

### *Liquefied Petroleum Gas (LPG)*

LPG is a mixture of 'heavy' gaseous hydrocarbons, particularly propane $C_3H_8$ and butane $C_4H_{10}$. These gases are heavy because they are denser than air, and easily liquefied under moderate pressure. LPG is obtained during the refining of crude petroleum or directly from underground deposits. LPG is used as a fuel and also as an aerosol propellant and as a refrigerant to replace chlorofluorocarbons. The latter has been phased out because it causes damage to earth's protective ozone layer.

### *Natural Gas or Liquefied Natural Gas (LNG)*

Natural gas is a mixture of 'light' gaseous hydrocarbons consisting of methane $CH_4$ and ethane $C_2H_6$, whichare lighter than air. Odorant is usually added to the gas to make it noticeable and objectionable for ease of detection. Liquefied natural gas is natural gas liquefied by compression. It is a good source of portable fuel.

### *Shale gas*

Shale gas is natural gas trapped in rock formations known as shale. In nature the gas can only escape through fractures in the rock formation. Fracking is the process of fracturing shale artificially by hydraulic power to release the gas. The process of fracking was developed in North America and has become the major source of gas for energy production since year 2000.

### *Carbon in Methane Hydrate*

Methane,consisting of one atom of carbon bonded to four atoms of hydrogen, $CH_{4,}$ is the lightest (having the lowest molecular weight) of all hydrocarbons. Methane is found as fossil deposits of natural gas formed under geological conditions and trapped under layers of rock.

Unlike other hydrocarbons, methane is also generated on land by ongoing anaerobic decomposition (decomposition in the absence of oxygen) of manure, municipal solid waste, including other forms of biomasscan be produced by anaerobic composting of biomass. Flooded rice fields produce methane from decaying vegetation. Methane is also produced in anaerobic processes of digestion in the stomachs of livestock. About 37% of on-going methane production is by animal digestion.Methane is also different from other hydrocarbons in that at freezing temperatures it can bond with water to form methane hydrate, also known as methane clathrate: $(CH_4)_4(H_20)_{23}$, which is white solid at ice temperatures.

Before year 2000, methane hydrate was an obscure substance about which very little was known. Its significance only began to be realisedafterlarge deposits were found in regions of permanent ice (permafrost) in ocean floor around at the bottom of the continental slopes at depths of 350 – 5000 m. The deposits are thought to have been formed through geological time by the action of bacteria on plankton that have died and accumulated at the bottom of the ocean. The deposits thickest around the continental shelves because that is where plankton is most abundant due to nutrients washed into the ocean from the land. Below a depth of 350 m the water is uniformly cold at 0-4$^o$C and the pressure exceeds 35 bar. Under these conditions, methane hydrate is stable. The deposits have accumulated through geological time and estimates of the amount vary from 500-2500 Gt to 1000-5000 GT of carbon.

Methane is a powerful greenhouse gas, many times more potent than carbon dioxide. It has a global warming capacity 34 times that of carbon dioxide (for the same mass) in a 100 year period. In a 20 year period, its warming capacity is 72 times that of $CO_2$. It is feared that with unrestrained global warming, methane hydrate may break down and its methane released into the atmosphere. Such events may have happened in the geological past and contributed to mass extinctions.

Under natural conditions, small amounts of methane escape from the methane hydrate deposits but are acted upon by deep-ocean bacteria and oxidised to $CO_2$ so that what escapes into the atmosphere is CO2, not methane. The process would increase the rate of ocean acidification and deplete the oxygen supply in the ocean. The depletion of ocean oxygen on a big scale would endanger fish and other marine animal life. The use of methane (e.g. as LNG), as a fuel, converts high-impact $CH_4$ to lower-impact $CO_{2.}$ Hence, the huge deposits of methane hydrate on the ocean floor may be considered as huge deposits of fossil fuel.

### *Carbon in Rocks in the Earth's Crust*

The largest amount of carbon on earth is stored in sedimentary rocks in the earth's crust. Mud, rich in decomposed plant matter, is changed into shale through heat and pressure, and such shale may be rich in carbon. Moreover, the shells and skeletons of marine animals accumulated in the sea floors over time are metamorphosed through geological processes into limestone and marble. Certain limestone formations may also have been formed by direct reaction between $CO_2$ and calcium in the ocean. Such rocky deposits may be uplifted to form hills and mountains. These rocks store 100,000,000 Gt of carbon. The storage of carbon in rocks is a stable form of storage.

The manufacture of cement from limestone contributes 5% of carbon dioxide emissions in the atmosphere. The process of making cement involves the breakdown of limestone $CaCO_3$ by heat to obtain CaO, with emission of $CO_2$. One tonne of cement results in the emission of 900 kg of $CO_2$ of which 50% is from the chemical process and 40% from the fossil fuel used to generate the heat required to drive the process.

### *Global Warming and Its Consequences*

The historical rates of exchange of $CO_2$ between the atmosphere, ocean, living organisms and soil are normal and natural because they have been long established and are finely balanced against each other.

The earth is heated up by solar radiation and in turn the earth radiates heat into outer space. Greenhouse gases like $CO_2$ retard the radiation of heat out of the earth. Life on earth has evolved around a stable balance between the amount of heat that comes in and the rate at which heat goes out. Any imbalance will have destabilising effects. The balance is now being upset by the rapid and massive increase in $CO_2$ in the atmosphere through combustion of fossil fuels.

Even a small rise of one or two degrees above the normal range, applied globally, can be expected to have big effects. It would increase the level of evaporation by which water is taken up as water vapour to form rain clouds. Increase in rainfall and shifts in rainfall locations may be expected and are indeed already apparent. The early melting of mountain snow and ice is affecting the flow of water in rivers, in particular the great rivers that start from the Himalayas and Tibet to feed the agricultural plains of China, India and Continental SE Asia. The thinning of polar ice caps is contributing to rising ocean levels.

Accordingly, the natural balance to which life and human development have become adapted for tens of thousands of years is being changed in a matter of decades. As a consequence, many species are likely to become extinct before they can adapt, especially species with long reproductive cycles because such species adapt slowly. Microorganisms and insects with short reproductive cycles will adapt much better than vertebrates and trees. Low-lying coastal areas, including major cities and agricultural lands, and low lying countries, risk being destroyed. Crop yields are likely to be depressed by temperatures to which the crop plants are not adapted. There will be many other effects, not all predictable.Inherently, although humans may adapt through technology, but the world will be a very different place and the poorer communities with fewer technological options will face a bleak future before 2050.

According to the 2014 World Development Report by the World Bank, on Risk and Opportunity, the number of natural disasters (droughts, earthquakes, floods and tropical storms in all parts of the world have been increasing in the past three decades. Table 2 provides the annual average number of natural disasters in South and East Asia. The warning signs of increasing climatic and geological instability are ominous.

Table 2.2 Annual Average Number of Natural Disasters in South and East Asia
(droughts, earthquakes, floods and tropical storms)

| Region | 1981 – 1990 | 1991 - 2000 | 2001 – 2010 |
|---|---|---|---|
| South Asia | 2.5 | 3.5 | 5 |
| East Asia | 1.9 | 2.8 | 4.1 |

In consideration of these and other warning signs, the UN Climate Change Conference held in Warsaw in November 2013, decided to prepare a Universal Climate Agreement in 2015, to be implemented in 2020.

### *Greenhouse Gas Emissions in Malaysia*

In 2000 the statistics for greenhouse gas emissions in Malaysia were reported as in **Table 2.3**. The greatest source of carbon dioxide emission is the energy industry, which generates electricity through the combustion of coal and hydrocarbons. The fuel mix for power generation in Malaysia from 1980 to the present and projected to 2030 given in **Table 4**, taken from the ASM

Advisory Report 1/2013 (Sustainable Energy Options for Electric Power Generation in Peninsular Malaysia to 2030, Academy of Sciences Malaysia).

In 2010, hydro and renewable energy sources accounted for less 7.3% of Malaysia's power generation. The rest (92.7%) was generated by fossil fuels: coal (36.5%) and hydrocarbons (56.1%). By 2030 the dependence on fossil fuels is expected to drop to 68%. However, non-hydro renewable fuels such as biomass are lowly regarded and are not expected to contribute more than 4% to electricity generation while nuclear is expected to contribute 6% in 2030.

Table 2.3 Greenhouse Gas Emissions in Malaysia in Year 2000

| Activity | % of total |
|---|---|
| Total: 167.44 Mt CO2 | 100% |
| Energy industries (generation of electricity, petrol refining, etc. | 35% |
| Transport | 21% |
| Manufacturing and construction | 16% |
| Forest and grassland conversion | 14% |
| Others | 14% |

Table 2.4 Fuel Mix for Electric Power Generation in Malaysia, With Projections to 2030

| Fuel Type | 1980 | 1990 | 2000 | 2005 | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|---|---|---|
| Natural gas | 7.5 | 15.7 | 77.0 | 70.2 | 55.9 | 25.0 | 21.0 | 25.0 |
| Coal | 0.5 | 7.6 | 8.8 | 21.8 | 36.5 | 45.0 | 49.0 | 43.0 |
| Hydro | 4.1 | 5.3 | 10.0 | 5.5 | 5.5 | 26.0 | 25.0 | 23.0 |
| Petroleum | 87.9 | 71.4 | 4.2 | 2.2 | 0.2 | 1.0 | 1.0 | <1.0 |
| Renewables (non-hydro) | 0 | 0 | 0 | 0.3 | 1.8 | 3.0 | 4.0 | 3.0 |
| Nuclear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.0 |

Source: Lian, After & Abdul Rahim 2011

The amount of coal produced in Malaysia is about 393,000 tons per annum, which represents 10% of total coal usage. The rest of Malaysia's annual coal requirement is provided by imports from Indonesia (84%), Australia (11%) and South Africa (5%). (ASM Advisory Report 2/2003).

Nonetheless, there is at present no plan to replace coal with locally-grown wood for energy production despite Malaysia's climatic suitability for growing wood. This is in sharp contrast with the projected 6% for nuclear energy by 2030.

The emissions from forest and grassland conversion, includingothersources, make a total of 28%, which would compriseof$CO_2$ emissions from conversion of forests, methane generated by growing rice, $CO_2$ emissions from agricultural soils, and methane from digestive processes in cattle. Of increasing concern is the emission of nitrous oxide from the use of nitrogen-rich fertilisers. Nitrous oxide $N_2O$ is 310 times as potent as carbon dioxide in global warming. However, there are no studies are available on the emission of nitrous oxide in Malaysian agriculture.

### *Measures for Reduction Of$CO_2$Emissions*

Current global initiatives to reduce carbon dioxide emission are focused on several actions of which the main ones are in the fields of energy-management, land-management and waste-management; all aimed at reducing the 'carbon footprint' of human activities, as follows:

1. Replacement of fossil fuels for generation of energy with solar, wind, geothermal, waves, mini-hydro, and nuclear options;
2. Improvement of design of buildings to reduce energy usage;
3. Adjusting air-conditioning and heating levels in public buildings to reduce energy consumption;
4. Reduction of energy consumption through better design of engines, vehicles, and industrial processes;
5. Protection and promotion of carbon sinks such as forestsand soils;
6. Increasing terrestrial carbon sinks through reforestation and tree-planting; and
7. Managing biomass waste to reduce emission of greenhouse gases and to produce energy and compost.

## 2.4 CARBON PRICING AND CARBON TRADING

Every human activity that generates greenhouse gases has a 'carbon footprint', for which, Wright, Kemp, and Williams, in the journal *Carbon Management*, had suggested the following definition:

*"A measure of the total amount of carbon dioxide ($CO_2$) and methane ($CH_4$) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent ($CO_2e$) using the relevant 100-year global warming potential (GWP100)."*

Hence, it is possible to calculate the amount of carbon dioxide that every activity generates. This 'carbon footprint' can be used to measure responsibility for climate change. A tax on pollution could be imposed to pay for activities that remove carbon dioxide from the atmosphere. Some countries are in progress of implementing such a tax. In light of that, numerous large corporations are already conducting internal audits on their carbon footprints to identify and reduce their main sources of pollution in anticipation of such a tax.

According to *The Economist* (December14, 2013), Microsoft has fixed a price of $6-7 per tonne of C, where as Exxon Mobil has fixed it at $60 per tonne. These figures are used to calculate the value of future projects and to guide investment decisions in the belief that a carbon tax is inevitable and is expected to be applied in many countries by 2020. The idea is to identify and restructure units that produce disproportionate pollution. Disney, a media conglomerate, invests in schemes to offset or reduce carbon emissions and charges the cost of these to its business units in proportion to how much they contribute to the company's overall emissions. In effect, this works like an internal carbon tax. The US Administration has estimated the cost of environmental carbon at $37 per tonne.

It is estimated that the 500 largest listed companies in the world emit a total of 3.6 billion tonnes (3.6 gigatons) of greenhouse gases a year. In Britain, the government has made it mandatory for companies listed on the main market of the London Stock Exchange to State Green House Gas (GHG) emissions in their annual reports.

In Malaysia, the Government has launched, in December 2013 a programme called MYCarbon under which companies and corporations are encouraged to voluntarily monitor and disclose their Green House Gas (GHG) emissions. This programme is implemented by the Ministry of Natural Resources and Environment in partnership with the United Nations Development Programme (UNDP) Malaysia. The main objectives of MYCarbon, as listed in the Inception Report of 12 February 2014, are as follows:

- To set up a globally recognised, standard corporate GHG accounting and reporting programme in Malaysia;
- To encourage corporate level carbon accounting and emission reductions; and
- To provide standards, guidance and support measures (training, fiscal and other incentives).

As a result, the development of a web portal (www.mycarbon.gov.my) has been initiated.

Apart from that, the International Convention on Climate Change negotiated in Rio de Janeiro in 1992 as well as the Kyoto Protocol of 1997 provided three mechanisms for countries to meet emission targets: carbon trading by which countries can trade their carbon credits with each other, joint implementation by which countries can undertake joint reduction projects and share the credit obtained and CDM (Clean Development Mechanism) in which developed countries can undertake emission reduction projects (e.g. creation of tree plantations) and obtain credits for themselves. The reduction of greenhouse emissions by 5% from 1990 levels would require planting 10 million ha per annum globally. (Azlan *et al*. 2010)

## 2.5 THE USE OF WOOD TO REPLACE COAL AS FUEL

Trees capture and store carbon as wood while they are actively growing. In the process, trees provide important ecological services in improving air quality, improving the landscape, improving the functioning of the water cycle, protecting soil, and providing biodiversity habitats. Wood is generally considered to be the best green alternative to coal because unlike coal, wood is renewable and Malaysia's wet tropical climate is ideal for tree growth. In using wood to generate electricity, the $CO_2$ emitted would be reabsorbed by continual replanting of trees for fuelwood. Hence, there would be no net increase in emissions.

For use as industrial fuel, wood would have to be prepared in a standardised form, e.g. as wood chips or wood pellets. Wood chips are relatively simple to produce from small-diameter wood; hence, even branches and twigs can be used. Pellets are produced by compressing wood particles. Wood for fuel can be produced in short rotations of 3-6 years, unlike wood for timber which requires trees to be produce large logs that are straight and cylindrical, in rotations of 30 years or more.

In Europe, wood pellets are already an important source of fuel for generation of electricity, exceeding solar, wind and other non-renewables. It is surprising that Europe has been able to promote the use of wood as non-renewable energy fuel. In contrast, Malaysia has lagged behind. With its tropical climate and abundant water resources, Malaysia can greatly increase its role as a producer of wood chips and wood pellets to replace coal. There are opportunities for at least doubling the carbon capturing capacity of trees with fast-growing trees. If plantations for wood pellets are established outside of forest reserves, in currently unproductive land, such plantations would not interfere with the environmental and economic benefits provided by normal forest management in existing forests.

In addition to that, there is land available outside of forest reserves in the form of neglected land. Such land is highly visible along the highways, especially in Pahang and Negri Sembilan. These lands are under private or State ownership but in which there have been no visible economic activity for many years because of urban drift and shortage of rural labour. Such lands could be put to use by planting with fast-growing trees on short rotations of 3-6 years. Such rotations could be managed on a contractual basis with the land owners without any need for change in landownership.

Thus, a well-managed programme should solve several problems simultaneously, namely, as follows:

- Put under-utilised land to productive use in wood production;
- Produce wood chips or pellets for renewable energy to replace coal;
- Increase the scope for innovation in the growing of trees to shorten rotations, in the development to harvesting technologies and in development of crop-rotation systems; and
- Provide an option for renewable energy that is not as controversial as nuclear.

The National Biomass Policy 2020 document (Version 2.0, 2013; *Agensi Inovasi Malaysia*) focuses on the use of biomass generated as a by-product of oil palm and other agricultural crops. Oil palm is the largest source of agricultural biomass, in the form of leaves and tree trunks. One of the uses for such biomass could be generation of electricity, which would require the leaves and trunks to be processed into pellets.

The Policy document notes that oil palm trunks and leaves have very high water content and one of the main costs in making wood pellets is incurred in the drying of the biomass. It would be much more efficient for oil palm biomass to be used for making chemical products that do not require drying. At present, the preferred use for oil palm leaves and trunks is leave them on the ground to fertilise the soil in oil palm estates, so strictly speaking oil palm leaves and trunks are not wasted or non-utilised.

According to the National Biomass Policy 2020 document, the cost of developing a wood pellet plant is RM30-40 million, using technology already available overseas, with a capacity of 100,000 tonnes per annum. The availability of oil palm biomass in volumes large and consistent enough to keep a chipping and pelleting plant in operation is highly doubtful. The supply of oil palm trunks is dependent on the rate of replanting, which is dependent on the economics of the oil palm industry, not on the requirements of a wood pelleting plant or a power generator.

R&D for a wood pelleting industry has to be focused on the development of suitable species, rotations and management systems that are optimised for wood pellet production, not on species and systems that have been developed for other purposes. The National Biomass Policy document mentions Acacia mangium from pulpwood plantations in Bintulu, as well as bamboos, as possible sources of biomass for pelleting. *Acacia mangium* would be a strong possibility, nonetheless, bamboos in the tropics are labour intensive to harvest because tropical bamboos grow in thick clumps with stems of different ages all mixed up in each clump. Selecting and pulling out individual stems that have matured is labour-intensive.

A power-generation plant based on wood pellets cannot be established on its own if there is no sustained supply of wood pellets. Landowners will not grow wood for energy if there is no buyer for such wood offering a guaranteed and attractive price. Any wood that is produced cannot be converted to pellets unless there is a plant to produce pellets on an industrial scale.

The rules on transportation of wood enforced by the Forest Department will have to be modified to allow wood to be transported to a wood-pelleting plant from privately-owned lands. The industry could also use the wood waste that is at present dumped into landfills or incinerated, including green waste from parks, gardens and roadsides, wood from the construction industry discarded after building, and waste from the timber-processing industries. The entire system has to be part of a deliberate and visible national target to reduce coal with wood. It is unlikely that such a system can be established by the private sector, because there are too many components involved. The best way to get going may be to establish some sort of Environmental Carbon Authority funded by Government on a pilot scale to develop the concept in one selected district or State.

### *Carbon Sequestration*

Carbon sequestration is the storage of carbon dioxide in a safe form so that it does not get into the atmosphere.

### *Sequestration of Carbon Underground as Carbon Dioxide.*

Engineers view carbon sequestration as the grand challenge for the 21st century. They have defined the problem as the development of systems for capturing and permanently storing the carbon dioxide produced by combustion. According to the US National Academy of Engineering, there are methods that already exist for key parts of the sequestration process. A chemical system for capturing carbon dioxide is already used at some facilities for commercial purposes, such as beverage carbonation and dry ice manufacture.

The same approach could be adapted for coal-burning electric power plants, where smokestacks could be replaced with absorption towers. One tower would contain chemicals that isolate carbon dioxide from the other gases (nitrogen and water vapour) that escape into the air and absorb it. A second tower would separate the carbon dioxide from the absorbing chemicals, allowing them to be returned to the first tower for reuse.

A variation to this approach would alter the combustion process at the outset, burning coal in pure oxygen rather than ordinary air. That would make separating the carbon dioxide from the exhaust much easier, as it would be mixed only with water vapour, and not with nitrogen. It's relatively simple to condense the water vapour, leaving pure carbon dioxide gas that can be piped away for storage.

In this case, though, a different separation problem emerges — the initial need for pure oxygen, which is created by separating it from nitrogen and other trace gases in the air. If that process can be made economical, it would be feasible to retrofit existing power plants with a pure oxygen combustion system, simplifying and reducing the cost of carbon dioxide capture.

Apart from that, advanced methods for generating power from coal might also provide opportunities for capturing carbon dioxide. In coal-gasification units, an emerging technology, coal is burned to produce a synthetic gas, typically containing hydrogen and carbon monoxide. Adding steam, along with a catalyst, to the synthetic gas converts the carbon monoxide into additional hydrogen and carbon dioxide that can be filtered out of the system. The hydrogen can be used in a gas turbine (similar to a jet engine) to produce electric power.

To store $CO_2$, several underground possibilities have been investigated. Logical places include old gas and oil fields. Storage in depleted oil fields, for example, offers an important economic advantage — the carbon dioxide interacts with the remaining oil to make it easier to remove. Certain fields have already made use of carbon dioxide to enhance the recovery of hard-to-get oil. Injecting carbon dioxide dislodges oil trapped in the pores of underground rock, and carbon dioxide's presence reduces the friction impeding the flow of oil through the rock to wells.

Depleted oil and gas fields do not, however, have the capacity to store the amounts of carbon dioxide that eventually will need to be sequestered. By some estimates, the world will need reservoirs capable of containing a trillion tonnes of carbon dioxide by the end of the century. This amount could possibly be accommodated by sedimentary rock formations with pores containing salty water (brine).

The best sedimentary brine formations would be those more than 800 meters deep; far below sources of drinking water, and at a depth where high pressure will maintain the carbon dioxide in a high-density State. Sedimentary rocks that contain brine are abundantly available, but the concern remains whether they will be secure enough to store carbon dioxide for centuries or millennia. Faults or fissures in overlying rock might allow carbon dioxide to slowly escape, so it will be an engineering challenge to choose, design, and monitor such storage sites carefully.

There for, concerns about leaks suggest to some experts that the best strategy might be literally deep-sixing carbon dioxide, by injecting it into sediments beneath the ocean floor. High pressure from above would keep the carbon dioxide in the sediments and out of the ocean itself. It might cost more to implement than other methods, but it would be free from worries about leaks. And in the case of some coastal sites of carbon dioxide production, ocean sequestration might be a more attractive strategy than transporting it to far-off sedimentary basins.

It is also possible that engineers will be able to develop new techniques for sequestering carbon dioxide that are based upon natural processes. For example, when atmospheric concentrations of carbon dioxide increased in geologic times to a certain unknown threshold, it went into the ocean and combined with positively charged calcium ions to form calcium carbonate – limestone. Similarly, engineers might devise ways of pumping carbon dioxide into the ocean in ways that would lock it eternally into rock.

***Sequestration of carbon in soil as charcoal (biochar or horticultural carbon)***

The growing of trees provides a form of sequestering carbon by locking it up as wood. When a trees stops growing, its carbon content is frozen until the tree dies and decays or until its wood products decay. To store carbon more permanently requires one additional step, which is to convert wood to charcoal. Charcoal is relatively stable in nature because it is not used by bacteria, fungi, insects or any of the organisms known to be responsible for biodegradation,

Carbon residues in soil, e.g. charcoal from forest fires or from open burning of rubbish, are said to be ‘recalcitrant’ as they do not break down easily. In Malaysia, the black soil (*tanah hitam*) that used to be available for horticulture was obtained from backyard rubbish dumps that were periodically set on fire. Contrastively, in the Amazon basin, the most fertile soils are *terra preta*, which is a black soil with a high charcoal content. These soils occur at the sites of ancient human settlements and are the result of mixing the burnt remains of plants into the soil through many generations of settlement. What this means is that carbon if sequestrated as charcoal can be put to good use in agriculture by incorporating it into soil (Ng, FSP, 2009, in “Horticultural carbon, terra preta and high-performance horticulture in the humid tropics” (*Journal of Science and Technology in the Tropics,* vol. 5, pp. 79-81).

To illustrate, a horticultural project has been running in Kuala Lumpur since 2004 using small charcoal particles as a horticultural medium, pure or mixed with soil. Known as the Secret Garden of 1Utama, this garden measures 2786 $m^2$ (30,000sqft) in size. The charcoal particles are 0.2 – 0.5 cm in diameter. Almost 500 species of plants have been grown successfully on it. Even paddy rice has been grown successfully on pure charcoal. Charcoal is half the weight of soil and particularly suitable for roof gardens. Mixed with soil it makes the soil open, porous and resistant to compaction. There is a growing movement of enthusiasts who view the use of charcoal in agriculture as the best method of carbon sequestration (the Economist August 29, 2009).

Figure 2.1 Charcoal in the form of horticultural carbon or biochar

Figure 2.2 The Secret Garden of 1 Utama - growing on horticultural carbon

On the ground, housing projects in Bandar Utama are now landscaped after incorporation of biochar into the soil using a rotovator. Grass and garden plants are planted in the biochar/soil mix without bringing in new soil from elsewhere. This method is labour-saving and cost-effective because imported soil is difficult to obtain, of unknown quality and often heavily weed-infested. The incorporation of biochar produces a much cleaner, predictable and better result.

The conversion of wood to charcoal involves simple technologies that are already well-known and but there is a need to improve efficiency. Some new designs claim to produce charcoal in 24 hours with close to 50% recovery of charcoal from wood, and 75% reduction of emissions. When carbon dioxide is converted to wood and then to charcoal, the carbon is stored for long periods. Hence, if broken up and used to improve soils, it would increase the cropping potential of soils although its storage period may be reduced through poorly-understood processes that have the effect of diminishing carbon particles in soil.

## 2.6 OTHER GEOENGINEERING SOLUTIONS TO CLIMATE CHANGE

More than two decades of UN discussions and negotiations have failed to effectively reduce emission of greenhouse gases. In fact, emissions are accelerating: a quarter of all the carbon dioxide ever pumped into the air by humans was put there in the decade between 2000 and 2010. The official ambition of limiting the global temperature rise to 2°C looks increasingly like a bad joke (The Economist Nov 23, 2013).

'Geoengineering' techniques, apart from direct storage of CO2 underground, are now being explored by scientists. Among such techniques is 'fertilisation' of oceans with iron to encourage growth of plankton. This is idea is based on evidence that iron is a limiting factor for plankton growth. When more iron is made available, plankton will multiply and absorb $CO_2$ in photosynthesis. When plankton ages and dies it will sink deep to the ocean floor and remain sequestered there. Other nutrients that may stimulate plankton growth are nitrogen and phosphorus. Other ideas include the deflection of sunlight from the earth through the use of a giant space mirror 'spanning 600,000 square miles', and the use of aircraft to dim the sun, mimicking the after-effects of volcanic eruptions by filling the upper atmosphere with a fine haze of sulphate particles.

Nonetheless, these measures will affect the whole planet and their consequences cannot be fully predicted nor finely controlled as in case of lab-scale experiments. We have only one earth, and no backup option. The practical, moral and ethical problems of geoengineering on a global scale would appear to be insurmountable. However, by 2050, such measures may look inevitable because by then, they may be less risky than doing nothing.

It is therefore necessary to take climate change seriously and to start on the long road to restoring ecological balance in the atmosphere and the ocean. Individuals, corporations and governments all have a part to play. The safest carbon sink activities are those connected to forestation and reforestation. Actions to increase plant cover in home gardens, roof tops, roadsides and wasteland, and the adoption of energy-saving habits in transportation, lighting, air-conditioning and waste management can and should be taken atalllevels of society.

# CHAPTER 3
## WATER

Water is indisputably the world's most precious resource, essential to sustain all life on earth. While 71% of the Earth's surface comprises water, only 3% is made up of freshwater, of which 69% is trapped as ice in polar glaciers and 30% are trapped underground as groundwater. This means that readily available surface water resources amount to only 0.3% of the total world's water, and this volume is found mainly in lakes, rivers, ponds and swamps (United States Environmental Protection Agency).

Water is essential for all major human activities and ecosystem functions. People need safe water for drinking as well as for other domestic uses. The lack of safe drinking water has resulted in an annual world death toll of more than 3.4 million people due to water, sanitation and hygiene-related causes (Water.org). As a socio-economic enabler, water is used in the cultivation of crops, fishery, fuelling industrial processes, power generation, tourism activities and as the medium of world trade (via shipping).

Water is also important in the maintenance of the environment; whereby pollution, unregulated abstraction and unsustainable use of this resource has jeopardised its ecological functions as well as reduced its availability. On the flipside, while there are beneficial uses for water, over-abundance and/ or water scarcity poses hazards to human population in the form of floods and drought. Adapting to these hazards is the other dimension in the management of water, especially in light of anticipated malevolent climatic change.

Although the science of water is already well-known, the wise use of available water necessitates that it be taken to another level of science and technology through innovative ideas and approaches to make it more effectively managed and efficiently utilised. It is in this context that water, being an important driver, enabler and supporter of life and the environment, is expressed under **Mega Science Phase 2**.

Photo 1: Rivers remains the main source of water for Malaysia

Photo 2: Lakes are important water bodies in the country

Photo 3: The ocean covers most of the World's surface

## 3.1 OBJECTIVE

The main objective of Water and the Environment for Mega Science Phase 2 is to seek a balance between wise use and management of water as a natural resource and water as a utility that sustains the value of the environment, and hence sustains life. Mega Science Phase 1 has already devoted at length on recommending water as a utility to create new wealth opportunities (2011 – 2050). All the ten recommended areas will need compelling innovative ideas and strong science and technology, to make a difference to the socio-economy of the country (See Box on recommendations). They will need more in-depth elaboration in future by researchers, but nevertheless, Mega Science Phase 2 has acknowledged them as significant for technological innovations for societal transformation, since all of them are dependent on the fundamental principles of water as a resource, and how well this resource is managed to sustain the environment.

This section on Water and the Environment will also be reviewing the types of impediments that can hinder the successful implementation of the previous recommendations, so that actions can be taken early to preclude any drawbacks in their implementation in future.

**Recommendations of Mega Science Phase 1**

- Eco-tourism around high ecological value sites
- Urban water-based tourism
- Market and export high quality water
- Clean water for aquaculture industry
- Malaysian brand for domestic water purification unit
- World leading tropical aquatic research and education
- Knowledge export
- Downstream water tapping
- Rainwater harvesting
- Zero pollutant discharge

## 3.2 WATER RESOURCES MANAGEMENT IN MALAYSIA

Worldwide, the importance of water in the environment and for development is realised as critical. Towards this end, the concept of Integrated Water Resources Management (IWRM) was established as an integral guiding principle at the international conferences on Water and the Environment in Dublin, and in Rio de Janeiro in 1992 and endorsed by the 2nd World Water Forum and the Ministerial Declaration at The Hague in March 2000. As an embracing concept in integrated water management, the Global Water Partnership

(GWP) has devoted its whole network in its advocacy of defining IWRM as "*a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*" (FAO).

Malaysia has adopted the IWRM concept as one of its key approaches for water resources management and in the process, has implemented reforms in water governance, legislation and institutions to professionally manage water. This largely reflects the Malaysian Water Vision, which was formulated in 2000 with the assistance of governmental and non-governmental agencies to help foster the country towards meeting its future water needs and to sustainably utilise its water resources. IWRM concepts and approaches have now formed part of the water agenda in the 5-year Malaysia Plans since the Eighth Malaysia Plan (2001 – 2005) to the current 10$^{th}$ Malaysia Plan (2011 – 2015).

An important challenge in the water agenda is the need for enablers to promote water sector reform, which is seen as a long term process. This is carried out through outreach and capacity building of personnel and institutions in the water sector to develop innovative ideas and solutions relating to wise water use; water and wastewater treatment; water reuse and recycling; water use and demand management; and development of alternative water resources (ibid.).

Even with the water sector reforms, the administration and management of water in Malaysia still remains an entangled complex web involving shared Federal and State mandates and responsibilities, as well as a multitude of government agencies, most of which have some form of overlapping jurisdictions and functions over water. While the purview over water lies with the respective State governments, the introduction of the Water Services and Industry Act 2006 has placed water supply and its associated services under the shared auspices of both the Federal and State governments, while water resource remains under the State jurisdiction.

Since then, several states have set up their own State Water Resource Management Authorities to manage their water resources, such as Sabah (1998), Selangor (1999), Pahang (2007) and Kedah (2008). Other states that have no formal water management agencies yet, are planning to do so in the near future to carry out this function (DID 2012). The whole business of water as a resource and water for utilities has generated a lot of interest with a propensity towards hydro-politics to become centre stage in the country at present and in future.

The National Water Resources Council (NWRC), set up as early as 1998 as the top advisory and coordinating body for the country for water resources, is however, lacking in full mandates to carry out its function effectively. It is anticipated that the passage of the draft National Water Resources Act, completed since 2011 (currently undergoing review by the Government (ibid.)), and the already adoption of the National Water Resources Policy 2012, there will be clearer jurisdictions over water resources security, sustainability and collaborative governance.

Meanwhile, the Water Vision and the National Water Resources Policy will need strong inspiration, political will and clear dispassionate STI approaches to address the major challenges in the water sector where management solutions clearly will affect the whole population in the country. Among these are:

a) **Water Stress** – The increased in urbanisation, industrialisation, population growth and water pollution have placed heavy stresses on the quantity and quality of water resources. Relieving these stresses could ensure water availability in quantities and quality for equitable allocation to all sectors.

b) **Sustaining Biodiversity** – The wise use of water is essential to sustain the ecological systems and their functions. If the ecological environment is degraded by pollution to the level of habitat destruction, it will disastrous to the population that depends on them for sustenance directly and indirectly. Thus, before any of these thresholds are reached, STI will have to provide pragmatic solutions to sustain the ecological environment in order for the population to survive.

c) **Climate Change** – Ramifications of climate change are expected in the weather systems in Malaysia, which in turn will affect water availability. Extreme weather conditions causing floods and droughts will become more common compared to the past. Adaptation methods to counter these extreme conditions will be necessary and the main question often asked is how STI can help prepare the country to adapt to these intense changes, where measures are required in the short and mid-term to address long-term effects.

d) **Balance Development, Water and the Environment –** The fast pace of development in the country has resulted in increasing water demand. Besides the pressures mentioned above, the need to transport water from source areas (most often outside the city limits) to the water-hungry population in the urban areas; managing point and non-point sources of pollution and stormwater runoff and floods, are by no means less stressful in the water sector as it gives rise to increased risks to the population and the environment. Managing all these pressures will require a complex andintegrated system. One concept is to develop integrated water resources management, and this will be discussed later in this Report by integrating elements of the natural water cycle into all planning design for the country (Subramaniam, December 24, 2012).

e) **Green Technology Growth** – Adapting and using new approaches to improve productivity and efficiency of water sector development will definitely come on-stream in future through STI. In the meantime, it is crucial to acknowledge and encourage technological investments to foster replacing polluting industries with cleaner production to sustain the environment and hence to sustain water resources in the country.

f) **Water as a Resource –** Water as a resource should be acknowledged wholeheartedly as it has the potential to be a vital generator of economic growth. For this reason, 'Green growth' as a concept is also being promoted by the World Water Council (WWC) to move away from traditional carbon intensive economic models and instead, adopt environmentally-sound economic growth based on renewable energy, efficient use of water and green technologies.

Hence, this paradigm shift in thinking is now being promoted in Malaysia, in certain sectors of the economy, as a response to the effects of ever increasing environmental cost incur by rapid economic growth and the effects of urbanisation on the water systems. In Malaysia, green growth is already associated with more efficient use of water and energy and the water utility sector is adopting green technology for water supply and wastewater treatment. It is also adopted by the industrial sectors, dam constructions, water-based tourism sector, including agricultural water use. It is therefore advocated in this Mega Science Phase 2 to give priority to innovations in the water resource sector by addressing it as a foundation to help create the new wealth opportunities in the country.

g) **Water as an NKEA –** In the water resource sector, green technology is less applied mainly because water resource *per se* is still not valued as an important resource. There is a perception that water is readily available and IRBM will take care of the management of water resource in the river basins to cater to all water demand needs. Indeed, this perception will have to be dispelled immediately.

One of the important approaches to change this notion is to promote water as one of the National Key Economic Areas (NKEA) to enable contributions through the Economic Transformation Programmes (ETP) to become a significant economic resource generator in the economy. To develop the water sector (resource and utility functions of water), water must be regarded as an integral part of the nation's vast natural resources with great potentials to contribute to the economy and societal development.

Photo 4: While Malaysia still has ample water resources, water stress still occurs in parts of the country

Photo 5: Many important ecosystems are facing pressure from development and pollution

Photo 6: Water is an important resource for various sectors and stakeholders

## 3.3 WATER SUPPLY AND DEMAND MANAGEMENT

Malaysia is considered as one of the few nations endowed with abundant water resources with annual rainfall of ~3,240 mm. However, rapid population growth, urbanisation, industrialisation, expansion of irrigated agriculture and climate change have increased the demands on water resources as well as contributing to its increasing water quality deterioration (Mohd Desa & Shafie) is expected to have a water surplus as shown in **Figure 3.1** (Falkenmark, Rockström & Karlberg 2009). Nonetheless, the variability in the distribution of rainfall often results in water scarcity in certain States such as Perlis and Melaka, while rapid industrialisation and urbanisation have caused water stresses in Pulau Pinang and Selangor (refer to **Table 3.1** for availability of water resources by states) (DID 2012).

In all cases, water demand in all states is expected to continue to increase (refer **Figure 3.2**). Among the competing water sectors, irrigation for agriculture accounts for the majority of water use (~70% of total water production) while it is also facing the highest rate of water losses (~55%).

Thus far, Malaysia has managed to meet its water demands through the continual expansion of surface water resources, mainly through development of structural works (dams, water treatment plants, water distribution systems, etc.) and through inter-State water transfers, for instance, the proposed Pahang-Selangor Raw Water Transfer Scheme).

It is likely that the capacity limit to develop and abstract water through dams, intakes and treatment plants will be reached in future, and further development of water resources will have to be in terms of alternative water sources to supplement deficits. One major alternative is to implement Water Demand Management (WDM) for all sectors and water through innovative ideas to reduce non-revenue water etc. (see **Section 4.1**).

Photo 7: Malaysia has a well-developed water supply sector but suffers from high non-revenue water

Photo 8: Dams provide storage for water

Photo 9: Leakage, aging piping network and water theft are contributors towards NRW

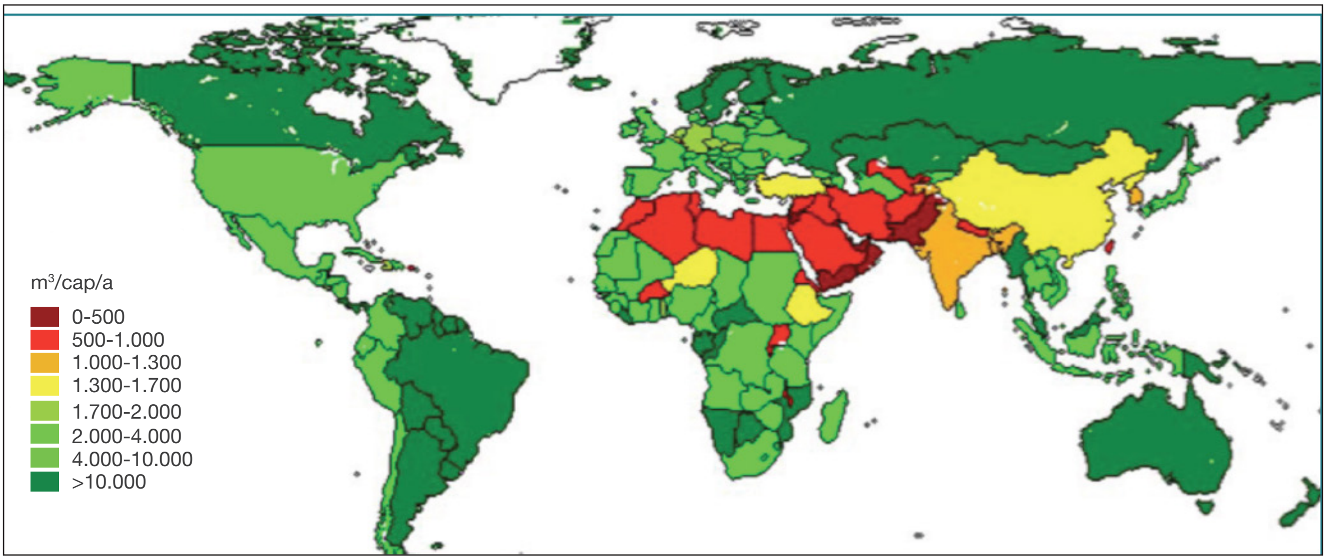



Figure 3.1 Water Surplus Countries in 2050

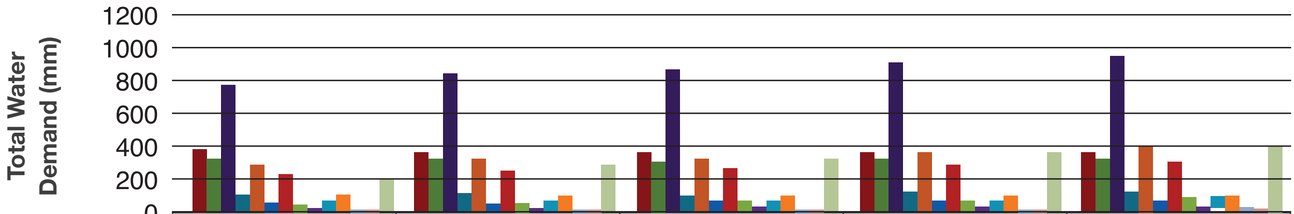
Source: Falkenmark, Rockström & Karlberg 2009

Note : The map illustrates in green the number of countries in 2050 facing water surpluses (>1,300 cubic metres per capita per year) and, in orange/red, countries facing deficits (<1,300 cubic metres per capita per year).

Table 3.1 Available Water Resources for Malaysia

| States | Rainfall | Actual \ Evaporation | Groundwater Recharge | Surface Runoff |
|---|---|---|---|---|
| Perlis | 1,880 | 1,290 | 120 | 470 |
| Kedah | 2,310 | 1,430 | 130 | 750 |
| Pulau Pinang | 2,350 | 1,430 | 120 | 800 |
| Perak | 2,420 | 1,320 | 170 | 930 |
| Selangor | 2,190 | 1,280 | 150 | 760 |
| Negeri Sembilan | 1,830 | 1,210 | 130 | 490 |
| Melaka | 1,880 | 1,210 | 100 | 570 |
| Johor | 2,470 | 1,130 | 200 | 1,140 |
| Pahang | 2,470 | 1,250 | 120 | 1,100 |
| Terengganu | 3,310 | 1,470 | 150 | 1,690 |
| Kelantan | 2,600 | 1,290 | 140 | 1,170 |
| Sabah | 2,560 | 1,190 | 190 | 1,180 |
| Sarawak | 3,640 | 1,250 | 240 | 2,150 |
| Labuan | 3,100 | 1,480 | 150 | 1,470 |
| Malaysia | 3,240 | 1,230 | 221 | 1,790 |

Source: DID 2012




| | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Perlis | 383.70 | 376.90 | 362.10 | 362.20 | 2050 |
| Kedah | 321.90 | 329.90 | 318.40 | 324.80 | 328.80 |
| Penang | 785.80 | 855.70 | 872.40 | 921.60 | 954.70 |
| Perak | 106.20 | 111.40 | 110.90 | 118.10 | 127.60 |
| Selangor | 294.00 | 329.30 | 344.20 | 373.80 | 401.50 |
| Negeri Sembilan | 59.10 | 63.50 | 64.80 | 67.60 | 70.90 |
| Melaka | 232.50 | 262.20 | 272.70 | 297.50 | 320.80 |
| Johor | 45.50 | 58.10 | 68.70 | 78.80 | 89.90 |
| Pahang | 25.80 | 32.80 | 32.60 | 34.10 | 36.90 |
| Terengganu | 70.50 | 78.00 | 78.40 | 86.50 | 90.60 |
| Kelantan | 110.50 | 110.00 | 108.40 | 109.80 | 110.70 |
| Sabah | 12.30 | 18.60 | 20.40 | 22.00 | 22.20 |
| Sarawak | 8.60 | 17.50 | 17.20 | 17.70 | 18.30 |
| Labuan | 213.10 | 289.40 | 336.40 | 370.80 | 403.30 |

Figure 3.2 Total Water Demand for Malaysia

Source: Department of Irrigation and Drainage 2012

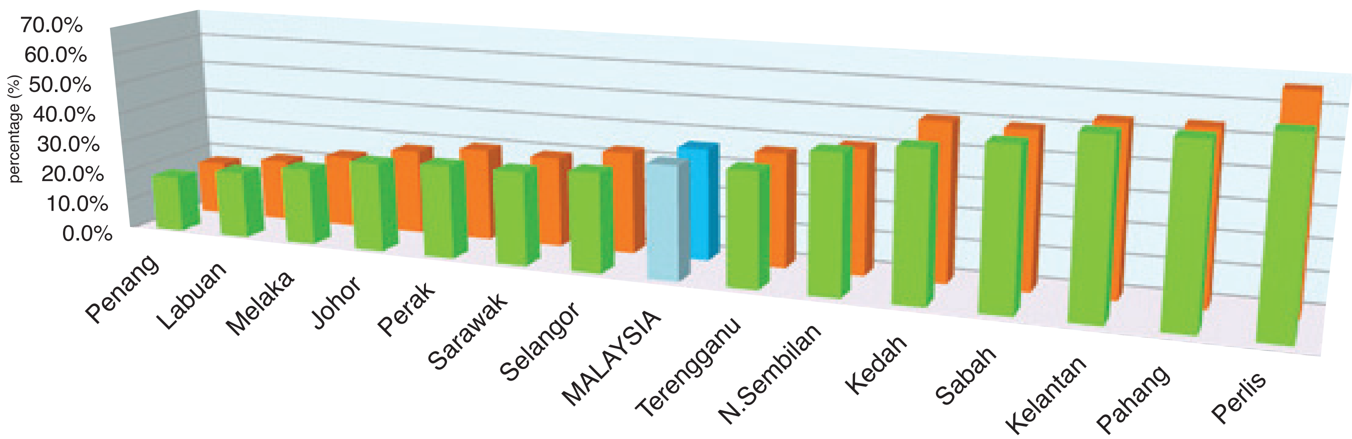
Note: Total water demand was estimated for potable water supply, irrigated paddy cultivation, non-paddy crops, livestock and fisheries.

## 3.5 REDUCING NON-REVENUE WATER

A major issue in water management in the country is the high rate of water loss where revenue could not be collected. Termed as Non-Revenue Water (NRW), it is water that has been produced and lost before it reaches the customer, either through physical loss (leaks in piping network) or apparent loss (theft, meter inaccuracies) (Wikipedia). Totally eliminating water loss is not feasible and would incur even higher capital and management costs, and thus water utilities often strive to achieve an Economic Level of Leakage (ELL), defined as the level whereby the cost of further reduction in NRW exceeds the cost to extract and treat water.

Based on an average arbitrary threshold of 30%, a State by State analysis of the NRW for Malaysia for the year 2011 and 2012 showed that most States have exceeded 30% NRW with the exception of Pulau Pinang (17.6%), Labuan (20.4%), Melaka (23.8%), Johor (27.8%) and Sarawak (29.4%), while Perlis has the highest NRW in the Country (66.4%) (refer **Figure 4.3)** (Suruhanjaya Perkhidmatan Air Negara).

Some of the main reasons for the high level of NRW are aging infrastructure (most of the pipelines are over 40 – 60 years old and awaiting replacement), illegal connections and low level of Active Leakage Control. While most of these issues can be resolved through investments for infrastructure replacement, the development of more efficient detection of leakages and management systems are crucial for long-term sustainability of water. It is one area that needs an innovative system to detect, monitor and manage the chain of water loss, not only for irrigation systems, but also in all water supply distribution networks to reduce NRW.




| | Penang | Labuan | Melaka | Johor | Perak | Sarawak | Selangor | MALAYSIA | Terengganu | N.Sembilan | Kedah | Sabah | Kelantan | Pahang | Perlis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 18.4% | 22.0% | 25.1% | 29.2% | 30.4% | 30.5% | 32.3% | 36.7% | 37.0% | 44.6% | 47.8% | 50.9% | 55.7% | 56.2% | 59.8% |
| 2012 | 17.6% | 20.4% | 23.8% | 27.8% | 30.1% | 29.5% | 33.1% | 36.4% | 36.8% | 40.4% | 50.6% | 49.9% | 53.9% | 54.2% | 66.4% |

Figure 3.3 Non-Revenue Water for States in Malaysia 2011 – 2012

Source: SPAN

STI investments in reducing NRW have been implemented in most countries. The most notable example approaches include the adoption of Smart NRW Monitoring and Management Networks in Thailand. An addition, breaking down networks into District Metering Areas (DMA) and Pressure Management Areas (PMA), is one way to effectively manage NRW. The use of software and hydraulic models can also assist in developing the optimal and most cost-efficient supply network.

These ideas have been explored by some water supply agencies in the country, and the next step is to develop these further especially on online monitoring systems and real-time control for the distribution system. An example of this application is seen in the Bangkok Metropolitan Water Authority which initiated a comprehensive NRW Reduction Programme, resulting in a reduction of NRW from 36% to 26% through the application of DMA and PMA, assisted with detailed hydraulic modelling of its pipeline network (Pedersen & Klee 2013).

Another example of advanced use of STI in water supply system management is through software solutions from IT companies. They offers applications to monitor, detect and prompt the repair on leakages, reduce water consumption and integrate the management of water infrastructure, assets and operations (Jerome, September 20, 2013). Technological advances include better sensor networks to detect problems, smart pressure monitoring system, and wireless automated metering including network distribution system monitoring solutions. Such forms of intelligent water networks/smart water grid will be essential for sustainable management of water networks, reducing the need to install new pipes while maximising use of existing pipelines. The major impacts would be reducing the loss of water resources throughout the distribution process, which ultimately increases available water for all sectors.

## 3.5 WASTEWATER RECYCLING

One avenue to reduce dependence on 'blue water' (water sourced directly from rivers) is to reduce water usage through wastewater recycling. Current available technologies include schemes utilising recycled wastewaters, which are treated to a standard acceptable for non-potable use e.g. factory process water. Uses for recycled water (with the exception of potable water for drinking purposes) currently adopted by some countries around the world include recharging groundwater aquifers, augmenting environmental flows, industrial reuse, domestic use (via dual reticulation systems) and irrigation of public spaces.

While harder to be accepted socially, the technology for reuse of treated wastewater as potable water for drinking purposes is also readily available. The current form of water recycling is through Indirect Potable Reuse (IPR), whereby wastewater is treated and then mixed into water reservoirs; going through a second round of treatment before being piped to consumers (the exception is Namibia which recycles water directly for consumption (Hagare, May 30, 2012)).

Examples of countries adopting wastewater recycling include:

- NEWater development in Singapore which utilises a series of treatment processes (conventional water treatment, microfiltration, reverse osmosis and ultraviolet disinfection) (Lim 2010).
- The Western Corridor Recycled Water Scheme in Queensland, Australia has a capacity of 236,000 $m^3$/day supplied from six of the region's major wastewater treatment plants. Water from the scheme is supplied to industries as well as used to augment the region's main storage reservoirs (Water Corporation).
- Orange County, California practices groundwater replenishment for drinking water whereby 265 million litres per day of recycled water is blended with groundwater and then pumped into the groundwater system. Abstracted water from the aquifers supplies half of the County's water supply (Government of the Republic of Korea 2012).

While such technologies exist, the high cost and technologically-intensive requirements of such schemes may preclude them from being adopted in Malaysia. But, as with most technologies, the unit cost of such systems will reduce over time, which will enable large-scale adoption in future but the research on them must begin as soon as possible. As available water decreases in congruent to increase in water stress areas in Malaysia, the current dependence on inter-basin transfer may also not meet future demands of water. Cases for the adoption of alternative water recycling technologies could therefore be one of the viable options especially in severe water stress areas (such as Perlis and northern Kedah, which have distinctively dry periods) and islands (where the cost of transporting water may be prohibitively high).

## 3.6 GROUNDWATER DEVELOPMENT

The National Economic Action Council (NEAC) in 1998 identified the potential for the development of groundwater resources. To date, groundwater resources remain largely unexploited in Malaysia. Groundwater exploitation as of 2010 was estimated to be 446 MLD (3% of total water utilisation in Malaysia) with expectations to increase to 3,304 MLD by 2020 (Mohamad & Abdul Karim).

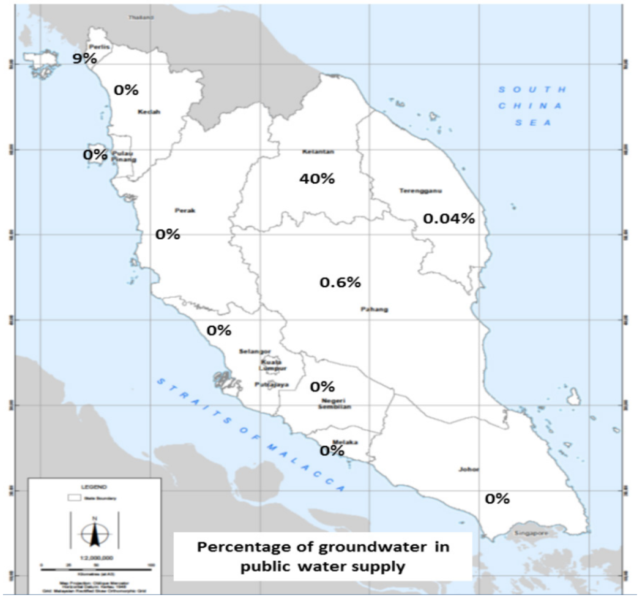
Currently, the major users of groundwater are industries, abstracting water for their operations and cooling systems (e.g. a 16 MLD of well water in Banting and 14 MLD of well water in OlakLempit, Selangor). Groundwater development for potable water use has long been practised in Malaysia albeit on small-scale, i.e. from wells in rural areas. Kelantan is one of the States that has embarked on groundwater abstraction on a large scale through Air Kelantan Sdn Bhd (utilising horizontal collector wells) while more recent venture includes those by Sime Darby at Batang Padang, Perak (currently discontinued). Conjunctive use of river and groundwater systems has also been developed in Kelantan through river infiltration systems (Air Kelantan Sdn Bhd).

In Sarawak, groundwater utilisation using tube wells began in 1954 in Sarikei and later developed in Bintangor and Sri Aman. For most coastal villages such as Belawai, Igan, Oya, Kabong, Pulau Bruit, Tatau and Limbang, groundwater abstracted from wells remains the main source of water supply. A large groundwater scheme was developed in Lambir to augment the Miri Water Supply Scheme. In Sabah, groundwater use is mainly from shallow wells and small-scale tubewells in Sandakan, Kota Belud and Kuala Penyu while in Labuan, groundwater wells in Nagalang were used conjunctively with surface water supply for the Island (ibid.).

Nonetheless, groundwater utilisation in Malaysia is still low (refer **Figure 3.4**). Some barriers identified include the fear of groundwater abstraction being unsustainable, lack of specialists in groundwater abstraction and management, difficulties in development of groundwater from aquifers (e.g. due to land rights), lack of enforcement and management, objections from non-governmental organisations for environmental degradation through land subsidence and lack of understanding and knowledge (Mohamed 2010).

One possible solution for sustainable groundwater supply is recharging the aquifers using treated wastewater/ rainwater (Aquifer Storage and Recovery) after abstracting it from the ground. Other conjunctive technologies include river bank filtration systems, pond infiltration systems and aquifer storage and recovery systems. In all cases, development of groundwater resources should be based on good science through detailed mapping of the actual groundwater resources, development of detailed hydrogeological models to determine actual flows, storage capacity and abstraction limits. If sustainable groundwater resource use can be achieved, Malaysia will have another 'tap' to supply water for the country.

**Groundwater in public water supply**




**Status of groundwater utilisation in Malaysia**

| Groundwater use in public water supply in Malaysia | | |
|---|---|---|
| Kelantan | 135 mld | 40% |
| Perlis | 9 mld | 9% |
| Sabah | 45 mld | 5% |
| Pahang | 6 mld | 0.6% |
| Terengganu | 0.2 mld | 0.04% |

More than 300 industrial wells in Selangor - industry sources

| Groundwater use in developed nations | |
|---|---|
| Denmark | 99% |
| Switzerland | 83% |
| England | 30% |
| USA | 20% |

**Groundwater is naturally better**

Figure 3.4 Groundwater Utilisation in Malaysia

Source: Mohamed 2010

## 3.7 RAINWATER HARVESTING

Rainwater harvesting is a process of collecting, diverting and storing rainwater for use. The concept was introduced by the Ministry of Housing and Local Government and the Ministry of Natural Resources and Environment as a means to reduce the impacts of the drought of 1998. In 2004, a cabinet paper was presented to the NWRC in 2004 for the installation of rainwater collection and utilisation system resulted in the decision that such practice is to be encouraged but not mandatory (DID 2012).

The National Hydraulic Research Institute of Malaysia (NAHRIM) and the Department of Irrigation and Drainage (DID) are two major agencies involved in promoting the use of rainwater harvesting, beginning with a series of pilot projects follows:

a) Domestic: Double-storey Terrace House at Taman Wangsa Melawati

b) Public: Mosque Complex, Taman Bukit Indah, Ampang, Sri Aman Girls School, Bukit Jalil Secondary School

c) Office Complex: DID Headquarters. NAHRIM Complex

In 2007, another concept paper was submitted by the Ministry of Natural Resources and Environment to the NWRC whereby it was decided that Rain Water Harvesting Systems would be included as a component in the Guidelines for Planning and Building Regulation under the Uniform Building By-laws, gazetted in November 2011 (amendment from the 1984 Uniform

Building By-law), which requires new semi-detached houses, bungalows and government buildings to install rainwater harvesting systems. To date, four States, namely Johor, Selangor, Perak and Kelantan, have gazetted it through the State Government Authorities, and the Federal Territory of Kuala Lumpur (Shaaban).

The uptake of rainwater harvesting is not too promising as mandatory installation of RWHS in new buildings has not been fully taken off. This is in contrast to countries like South Korea, which have mandated that all new residential and commercial development are required to include some form of rainwater harvesting. Star City located in Jayang-dong, Seoul, South Korea, is an example of a township where RWHS via rooftop rain collectors and terrace level garden infiltration systems (ibid.) have been practised.

## 3.8 FLOOD STORAGE PONDING SYSTEMS

Malaysia has mooted the use of flood storage ponds to collect river and rainwater, such as the Batu Pond as possible water to overcome water scarcity issues, but it has yet to overcome problems of polluted runoff, technical and cost issues (DID 2012). Another example is the recent proposal to convert ex-mining ponds, such as in Bestari Jaya, by LUAS, for dual-purpose flood and water storage ponds (Subramaniam, December 24, 2012).

Nevertheless, Malaysia is still in the process of anticipating on implementing measures to capture rainwater as a resource directly to supplement water reserves especially during drought periods. With its abundant rainfall and excess runoff during the raining seasons, such sources of water can be a huge benefit especially when relevant technological advancement, pragmatic policy implementation and incentives can allow for large-scale implementation nationwide.

## 3.9 DESALINATION

Desalination is the process of removal of dissolved minerals and mineral salts from feedwater (usually seawater). The technologies most commonly used for desalination are Multi-Stage Flash (MSF) distillation (utilising steam) and reverse osmosis (using membrane technology). The drawback of desalination is the high cost, potential environmental impacts and high energy consumption (energy accounts for a third of total cost of desalination), which limits its use (Future Direction Pte Ltd 2011). Most of the technology's adopters are from the Middle East where freshwater is scarce and water tariff is low (refer **Figure 3.5**).

Hence, so far, desalination is not widely adopted in Malaysia due to the abundance of freshwater, low water pricing and high cost of desalination technology. One avenue for adoption of desalination is on islands, which have limited freshwater and are cut off from freshwater supply networks in the mainland and where cost of laying seabed pipes or transporting water via barges is prohibitive (DID 2012). Development of desalination systems would be a long-term alternative option depending on the water stress faced by the country and only when other alternative water sources options have been exhausted.

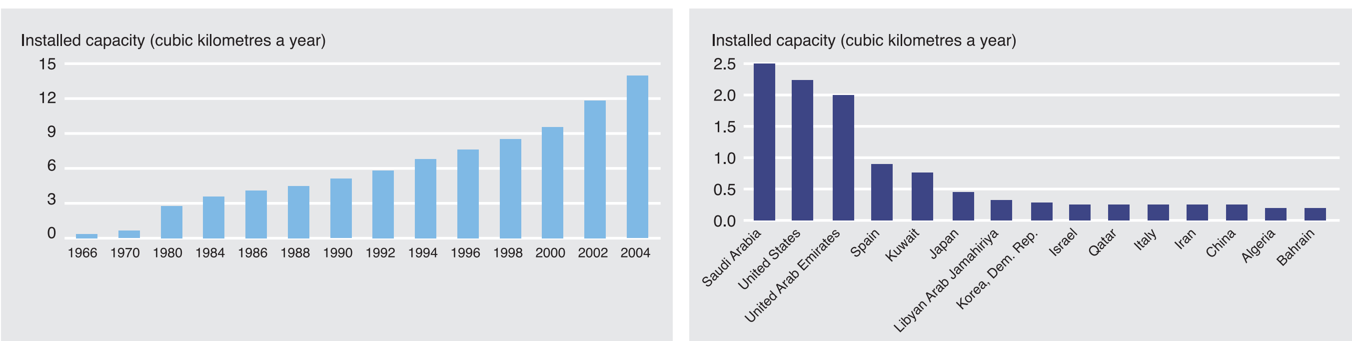



Figure 3.5 Volume of Desalinated Water Produced Worldwide

Photo 10: Groundwater remains an untapped resource

Photo 11: Wastewater recycling for industrial application and potable supply

Photo 12: Stormwater runoff and rainwater harvesting

## 3.10 WATER POLLUTION CONTROL AND MANAGEMENT

Water pollution control is primarily under the purview of the Ministry of Natural Resources and Environment (MoNRE) via the Department of Environment (DOE). Under the Environmental Quality Act 1974 (Act 127), specific legislations regulate discharges from point sources such as the palm oil and natural rubber industries, industrial discharges, sewage treatment plant discharges, leachates and scheduled wastes. The table below highlights some of the regulations pertaining to water pollution control:

| |
|---|
| Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977 |
| Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations 1978 |
| Environmental Quality (Scheduled Wastes) Regulations 2005 |
| Environmental Quality (Sewage) Regulations 2009 |
| Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 |
| Environmental Quality (Industrial Effluent) Regulations 2009. |

The complexity in the management of water pollution and pollution source control is compounded by various government departments and agencies sharing jurisdictions over water resources. These include the Department of Agriculture (irrigation and agriculture), Department of Minerals and Geosciences (groundwater management), Water Supply Department (water supply), Ministry of Health (water supply), local authorities (urban discharges, erosion and sediment control), DID (water resources), Suruhanjaya Perkhidmatan Air Negara (SPAN – water regulators of water services industry) as well as State Water Agencies, e.g. LUAS (DID 2012). Furthermore, river water quality monitoring by DOE showed that out of the 473 monitored rivers or segments of rivers in 2012, 59% were found to be clean, 34% were slightly polluted and 7% polluted as shown in **Figure 3.6**.

Pollution loads in freshwater are contributed by both point and non-point sources pollutants. An assessment by DOE of three main pollutants, Biochemical Oxygen Demand (BOD), Suspended Solids (SS) and Ammoniacal Nitrogen (AN), in terms of pollution loads, showed that the main sources of these three main pollutants were from Sewage Treatment Plants (STPs), followed by animal farming and food services (refer **Figure 3.7**).

In terms of marine waters, the Marine Water Quality Index, developed in 2012 and subsequently applied in assessing the marine water quality for coastal, estuarine and island waters, showed that they were also polluted. A summary of water quality for these areas is shown in **Table 3.2**.

Table 3.2 Summary of Marine Water Quality

| Monitoring Programme | Total Stations | Total Analysed | Excellent | Good | Moderate | Poor |
|---|---|---|---|---|---|---|
| Coastal | 168 | 155 | 1.9% | 20.6% | 71.6% | 5.8% |
| Estuary | 78 | 69 | 1.4% | 11.6% | 69.6% | 17.4% |
| Island | 93 | 86 | 15.1% | 20.9% | 60.5% | 3.5% |

Source: Departmen of Environment (DOE) 2012

Photo 13: Industrial discharge affecting a river

Photo 14: Land clearing for development and agriculture leads to erosion and sedimentation

Photo 15: Sewage is a main polluter to waterways

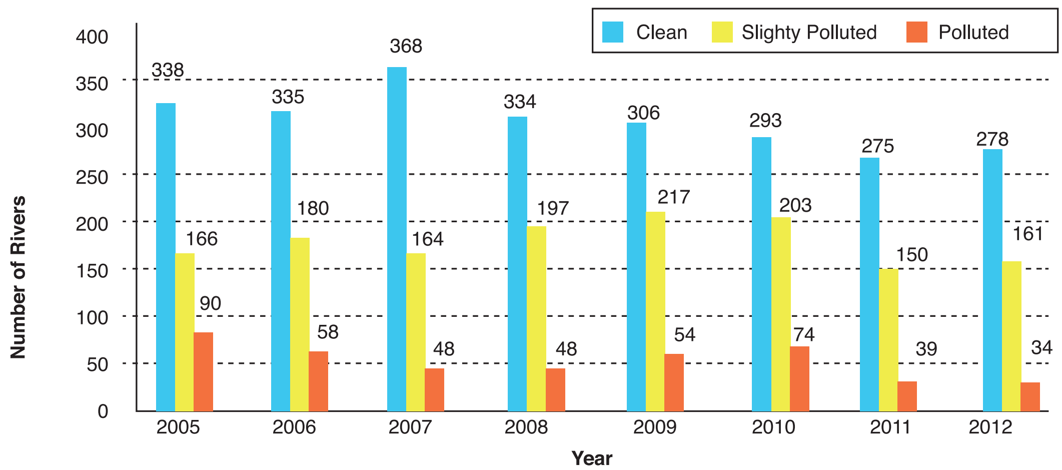



Figure 3.6 Water Quality Status for Malaysian Rivers 2005 – 2012

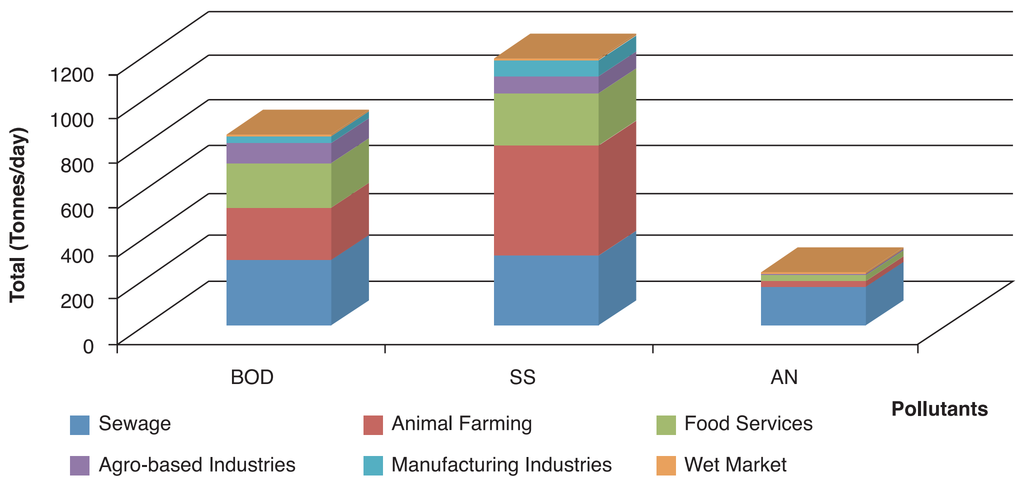



Figure 3.7 Pollution Loading by Sources for Year 2012

Source: DOE 2012

## 3.11 NON-POINT SOURCE AND NOVEL POLLUTANTS MANAGEMENT

One aspect of water pollution management that requires further scientific and technological innovative development is the control of non-point sources of pollution such as nutrient loading, land clearing and stormwater runoff. While there are mechanisms for management of erosion and sedimentation prevention and control with existing legislation and management practices in the country, most often rampant land development results in increasing Total Suspended Sediments (TSS) and turbidity in rivers and lakes. One case example is the Habu Dam in Cameron Highlands, which has been silted up due to land development within the reservoir catchment, and inadvertently leading to a reduction in reservoir storage capacity that lowers the hydropower generation potentials TNB 2011. DOE is now proposing amendments to the environmental legislation to address more effectively the control of pollution sources.

Other non-point source pollution that has significant impacts on water bodies and the environment are increasing use of nutrients and pesticides in agriculture. Already the leaching of nutrients has led to several visible impacts such as the eutrophication of lake water bodies. The Study by NAHRIM and ASM has indicated that nearly 60% of the 90 major lakes in Malaysia are eutrophicated. Other indicators associated with threshold limits of nutrient loadings are the red tide phenomenon in Sabah and weed infestations in coastal areas and lakes.

Unlike point sources, control of non-point sources is more difficult as they are diffused. In respect to non-point sources of pollution, Malaysia has yet to develop the means to monitor, control and mitigate such sources effectively except in certain landuse areas where there is control of point source pollution such as in large industrial complexes and residential and commercial areas through wastewater treatment, as a means to render low, the non-point pollutants in receiving waters.

One of the critical non-point pollution that is often overlooked in the country is the scientific study of novel or micro-pollutants in the water. These are the Endocrine Disrupting Compounds (EDC) from Pharmaceuticals and Personal Care Products (PPCP). Most of these pollutants are a result of modern human lifestyles, which are released as chemicals into the environment and which may have impacts on human health and the aquatic environment. Over the years, traces of these novel pollutants have been discovered in water and soil samples. The effects of these chemicals on human health and the environment is not well studied but the prevalent use of hormones, antibiotics and steroids may have far reaching consequences such as bio-accumulation of such chemicals in the aquatic environment (PPCP 2011). Current wastewater treatment technology is not equipped to remove PPCPs, and more basic research is needed in this field.

Other sources that are harder to control include agri-businesses which depend heavily on drugs to shorten livestock maturity time, improve yield and immunity to diseases. Likewise, use of drugs in the aquaculture sector is also not well studied. The United States Environmental Protection Agency (USEPA) has identified nearly 100 PPCPs in the country's waterways and drinking water samples (ibid.).

Thus far, Malaysia has focussed on management of conventional pollutants while the impacts of novel pollutants are still not well researched and studied. The fact that not much is known about the impacts of such modern day products on the environment and waterways is a call for more basic scientific research into this field. Key research areas should include identification of sources of such pollutants, their fates and transport through the environmental systems, exposure pathways and their effects on humans and the ecosystems. Without sound scientific data on how such point and non-point pollutants behave in the environment, appropriate mitigation measures cannot be developed to address their threat.

Photo 16: Erosion and sediment control

Photo 17: Stormwater runoff is often polluted by sullage and sewage

Photo 18: Novel pollutants are a growing concern

## 3.12 POLLUTION LOAD LIMITS

Pollution loads in Malaysia are benchmarked by concentration limits as defined by the regulations under the Environmental Quality Act 1974 (refer **Section 5.1**). For industrial and sewage discharges, discharge limits are to adhere to either Standard A or B (depending on the location of the discharge outlet in relation to the nearest water intake point). While the imposition of concentration limits addresses water pollution in general, it does not address the wastewater load discharged into a water body.

The DOE has throughout the years carried out water pollution studies of river basins with poor water quality (Class IV and below), having high value ecosystems or facing major landuse/ pollution issues (Sungai Prai, Sungai Merbok, Sungai Linggi, Sungai Kinabatangan, Sungai Kuantan, Sungai Melaka, etc.). Presently, the pollution of rivers are still prevalent (as evident by the number of polluted to slightly polluted rivers referred in **Figure 3.6**) even with pollution limitations in place. In cases where the quantity of discharge is significant or that the carrying capacity of a stretch of river is exceeded, this would mean that the waterway will still be impaired, even as the pollution source in certain stretches adheres to the concentration limits.

Rather than a concentration-based standard, the use of a load-based limitation or standard would be more effective to indicate the overall quality of water within a water body. Total Maximum Daily Load (TMDL) is a load-based limitation indicator. It is a calculation of the maximum amount of a pollutant that a water body can receive and still meets the water quality standards by an allocation of that load among the various sources of that pollutant (USGS). This mechanism not only indicates the condition of the water body, but also the required standards needed to protect it. Thus, TMDL is an option that can be adopted for rivers where the river capacity has been exceeded even after all technological controls have been adopted, such as, Best Available Technology (BAT) and Best Possible Technology (BPT). These rivers can then be managed of their excess pollution loads by further limiting pollution loads into the water body.

The implementation of TMDL requires research into areas such as river carrying capacity, pollution load studies, assessment of pollutant fates and also the development of accurate computer models to predict pollutant dispersion throughout the basins. In addition, TMDL values must also be revised from time to time. This is because there is more data is available, and there is a better understanding of the river systems. Pilot implementation of TMDL programmes can be carried out to address the nation's most polluted rivers which are listed below:

| State | River Basin |
|---|---|
| Kedah | Merbok |
| Pulau Pinang | Pinang, Perai, Juru, Jawi |
| Perak | Raja Hitam |
| Selangor | Buloh |
| Melaka | Merlimau, Seri Melaka |
| Johor/ Negeri Sembilan | Muar |
| Johor | Rambah, Pasir Gudang, Tebrau, Segget, Kempas, Danga, Pontian Besar, Sanglang, Air Baloi |
| Kelantan | PengkalanChepa |
| Terengganu | Kemaman |

Photo 19: Environmental standards may not be adequate to prevent degradation of water resources

Photo 20: Wastewater treatment systems

Photo 21: Rehabilitation of nation's most polluted rivers are critical

## 3.13 POLLUTION MONITORING NETWORK

Malaysia manages its rivers through Integrated River Basin Management (IRBM) whereby all major rivers and their tributaries are grouped into their respective river basins to be managed as a single hydrological unit. However, currently, only LUAS now has set forth a comprehensive river basin management plan that includes river monitoring plans for the Sungai Selangor and Sungai Langat basins within its jurisdiction (Lembaga Urus Air Selangor (official website of LUAS)). Other states are trying to institute specific legislations to implement IRBM such as Kedah, Pahang, Johor, Sabah and Sarawak. The delay in other States could be due to complex problems of multi-jurisdictional or trans-boundary river basins, which could complicate basin management (DID 2012).

While policy, institutional and legal requirements to manage river basins are important, the inadequate information of various river basins means that comprehensive planning for pollution controls cannot be comprehensively carried out. Likewise, computer models to determine river capacity, environmental flows, pollution fate and hydrological and hydraulic regimes of the rivers, are all constraining the management of river basins. Meanwhile, pollution control relies on obtaining reliable information to determine the sources of pollution and to ensure compliance to pollution limits set. Water pollution monitoring in Malaysia is mainly carried out through manual sampling of water bodies and conventional laboratory analysis. At present, the only continuous monitoring stations under DOE are located along Sungai Linggi, Sungai Jinjang, Sungai Melaka, Sungai Sarawak, Sungai Skudai, Sungai Selangor, Sungai Perak, Sungai Labu, Sungai Rajang and Sungai Putat (DOE 2013).

Many other government agencies have also developed automated data collection/ forecasting systems, such as the hydrographic network and flood forecasting and monitoring system by the DID; meteorological data collection system and tsunami warning system by the Malaysian Meteorological Department (MMD) as well as tidal stations networks by the Department of Survey and Mapping Malaysia (JUPEM) (Teh). In order to obtain accurate and up-to-date data on the environment, the application of automated and real-time system for pollution monitoring network is required to be developed and implemented. These systems should also be coupled with early warning systems to trace pollution events and also a Decision Support System (DSS). One aim of IWRM is to manage each river basin as a single management unit. Monitoring will allow for basin managers to gather essential information to support decision making.

Automation of water quality sampling is usually limited due to the high cost of such systems. The available sensors and sondes used for in-situ water quality monitoring were also previously limited but development of a wider range of sensors that can be deployed in the field and report in real time via wireless technology is emerging. Measurement instruments for in-situ physical-chemical parameters are already available for Dissolved Oxygen (DO), Electrical Conductivity (EC), pH and temperature while optical transmitter measuring light absorption by particles can measure TSS and ion selective electrodes are used to measure nutrient levels (Environmental Technology Online (ETA)).

The newer sensors are also being researched to detect bacteria, pathogens and novel pollutants, such as bio-sensors, DNA arrays, microbial chips, molecular fingerprinting, nano- and multi-contaminant probes. Wireless sensor networks which allow remote monitoring of water quality can be found in the market but cost may prove prohibitive. The advantage of these systems is that they offer long-term cost savings and provide continuous monitoring data (Global Environment Centre Foundation; ETA).

Furthermore, the implementation of improved monitoring systems in Malaysia are still limited due to the fact that many of the technology required are developed outside of the country and the cost of importing and adapting such systems are high. At present, though, there is no single local industry focusing on laboratory and analytical instrumentations R&D. The other prohibitive factor is the cost to maintain such systems and lack of capacity building to train local personnel to develop, install, manage and maintain these systems.

### *Ecological and water resource sustainability*

The ecosystem in Malaysia faces many issues, such in the overuse of water resources, degradation of natural habitats and water pollution. Development within river basins often stresses the river systems, which in turn affects the aquatic ecosystem and also the ecosystem services to humans.

### *Environmental flows*

In terms of sustaining the environment, an important component is environmental flow. The International Union for Conservation of Nature (IUCN) describes "environmental flow" as water required in a water body to support aquatic ecosystems. Freshwater ecosystems are losing a large proportion of their species and habitats compared to terrestrial and maritime ecosystems, due to insufficient environmental flows. The two main threats to environmental flows in rivers are from dam construction and from unsustainable water abstraction from rivers. In some cases, many of the world's largest rivers such as the Yellow River (China), Indus (India) and Murray (Australia) and Mekong no longer reaches the sea on anticipated periods of time (World Wildlife Fund (WWF) 2010).

Restricting flows through impoundment compromise the downstream environment, where there is insufficient water to support downstream habitats, mangroves, oyster beds, aquaculture areas and firefly sanctuaries. The aquatic environment has evolved over time to the natural hydrological cycle of rivers and tides. By damming and changing the flow condition of the river, it will inadvertently reduce flows to flush out sediments, or inversely, restricts sediment to downstream deltas and possibly increases saline intrusion from the estuary with overall effects on the ecosystem health (ibid.).

In determining environmental flows, the three major components are: baseline river flows based on day-to-day or seasonal variations, ecosystem adaptability to changing river conditions and also communities, which depend on the river ecosystem for their livelihood. The environmental flow requirements must balance the minimum flow release to the downstream river to meet the environmental flow objectives. There are various methods to determine environmental flows and some of the methods are provided in **Table 3.3** taken from the NWRS (DID 2012).

Table 3.3 Environmental Flow Determination Methods

| No | Approach/ Estimation |
|---|---|
| 1 | 10% Average Annual Flow (SFF) applied as a rule of thumb in the NWRS 1999 |
| 2 | Low flow of 7Q1, 7Q5 and 7Q10 (7-day low flow for 1, 5 and 50 years) |
| 3 | Tennant (Montana) Method |
| 4 | Smakhtin and Eriyagama Method (Recommended by NWRS 2011) |

Photo 22: Water release from dams needs to provide adequate environmental flow

Photo 23: Ecological flow is important to maintain important riverine ecosystems

Photo 24: Competition for water resources may lead to reduced water in the natural system

## 3.14 ECOSYSTEM SERVICES

Humans depend directly and indirectly on the health of ecosystems as well as the services they provide. Ecosystem services refer to the benefits derived from the ecosystem. The concept for PES as a market-based tool is to enable financial incentives to be allocated by beneficiaries of ecosystem services (refer **Figure 3.8**) to compensate individuals or organisations for conserving the natural resources.

Ecosystem services recognise that the environment has intrinsic and economic values and managing it, is equivalent to managing a natural resource. The direct beneficiaries of the services provided are many and by providing suitable incentives for maintaining or restoring the land for the desired environmental services and the value of the services provided be will tremendous as shown in **Figure 3.8.**

The PES schemes can be in various forms and some existing examples are shown in **Table 3.4**. Implementation of PES may require contractual negotiations between multiple parties comprising of the 'beneficiary' who is deriving benefits from the service and thus willing to pay for such services and the 'service provider' who agrees to conserve the ecosystem to ensure that the benefits are derived.

The problems in implementing PES lies in quantifying and monetising the benefits from such ecosystem services, identifying the potential beneficiaries, developing an equitable market system for PES trading and setting up the legal and institutional framework to regulate such a system. PES can be financed through various mechanisms such as self-organised private deals, public payment schemes, open trading of environmental credits and eco-labelling/ certificates (Khalit, Febuary 14, 2012).

| Provisioning Services | Supporting Services | Regulating Services | Cultural services |
|---|---|---|---|
| • Food<br>• Fresh water<br>• Fuelwood<br>• Fiber<br>• Biochemicals<br>• Genetic resources | • Services nessary for the production of all the other ecosystem services<br>• Soil formation<br>• Nutrient cycling<br>• Primary production | • Benefits obtained from regulation of ecosystem process<br>• Climate regulation<br>• Disease regulation<br>• Water regulation<br>• Water purification | • Nonmaterial benefits obtained from ecosystems<br>• spiritual and religious<br>• Recreation and tourism<br>• Aesthetic<br>• Inspirational<br>• Educational<br>• Sense of place<br>• Cultural heritage |

Figure 3.8 Ecosystem Services as Defined by the Millennium Ecosystems Assessment

The introduction of PES in Malaysia is still largely being developed, but no national policy or strategy exists to date. Several government and non-governmental agencies have spearheaded the process on its development and implementation including the Ministry of Natural Resources and Environment (MoNRE), Ministry of Finance (MOF), Economic Planning Unit (EPU), UNDP Malaysia and various research institutes (GRID-Arendal 2012). The clearest example of PES currently practised in Malaysia is in the form of National Parks, marine parks and forest reserves where visitors to such areas are required to provide entrance fees and other permits.

The most recent development is the dispute between the State of Pulau Pinang and Kedah on water rights and the ecosystem services provided by the Ulu Muda Forest Reserve, which acts as the watershed supplying most of the water resources to both states. Instead of conserving the forest, logging remains a more favoured form of income for the state, foregoing logging would mean losses in terms of timber sales. Among the areas that need to be further developed in order to settle such disputes include: the need for a mechanism to evaluate the ecosystem services contribution, the need for a system to regulate PES and the issue of governance (Free Malaysia Today, July 8, 2013).

Photo 25: Flooding occurs as more people live within floodplains

Photo 26: Watersheds are important to ensure sustainable water resources

Photo 27: Recreational and tourism benefits from ecosystems

Table 3.4 Examples of Markets for Ecosystem Services

| **Ecosystem Services** | **PES Schemes** |
|---|---|
| Carbon sequestration and storage | • Includes activities that mitigate carbon emissions or increase carbon sinks and positively impact on climate regulation<br>• Include prevention of deforestation, decreasing impact of logging or preventing drainage of wetlands<br>• Planting of trees (enrichment forestry), managing agricultural cropping practices and establishing grasslands<br>• Carbon emissions trading through carbon credits generated through government issued permits or project-based credits. Carbon emitters exceeding regulated emissions (carbon cap) can purchase carbon credits to offset CO2 emissions. Previously this was carried out under the Clean Development Mechanism (CDM) under the Kyoto Protocol<br>• The current regime for carbon markets is through the United Nations collaborative programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD)<br>• Currently, marine and coastal systems have yet to be developed to store 'blue carbon' and are being studied as they are believed to be able to store 50 times the carbon as those of terrestrial sinks |
| Biodiversity conservation | • Conservation of natural habitats and ecosystems such as through national parks, nature preserve, conservation areas and landscape conservation<br>• Conservation and propagation of rare and endangered species including control and removal of invasive species<br>• Restoration of degraded habitats and the maintenance of native plant species<br>• Low impact farming or development initiatives<br>• Markets for biodiversity conservation is not as well developed as other PES markets being mostly led by government agencies for the conservation of areas of high value biodiversity, payments for biodiversity management or eco-tourism |

| Ecosystem Services | PES Schemes |
|---|---|
| Watershed Services | • Improvement of water quality and quantity through rehabilitation of degraded areas, soil conservation, improved farming practices, protection of forest areas, etc<br>• Reduced erosion and sedimentation.<br>• Maintaining watershed for flow regulation and protection of strategic water sources.<br>• Payment for Watershed Services (PWS) is widely gaining ground in developing IWRM for watersheds. Most of the existing PWS schemes worldwide (a total of 113 active schemes worldwide worth a total of USD50 billion) are government or non-governmental organisation (NGO) led. |
| Landscape/ scenic beauty services | • Ecosystem provides non-material services such as tourism, recreation and cultural, and spiritual/ religious values.<br>• Habitat preservation through management of natural landscapes.<br>• Most of the market is based on ecotourism whereby tourists pay (entrance fees, license, facility rental, etc.) to view landscapes or carry out activities within areas of scenic beauty. Payment goes towards maintaining and conserving the habitats and ecosystems. |

## 3.15 WATER FOOTPRINT/VIRTUAL WATER

The water footprint concept was introduced by Hoekstra in 2002 as an indicator of direct and indirect water use of a consumer/ producer. Water footprint in a product is the volume of freshwater used to produce the product, measured over the full supply chain. Blue water footprint refers to consumption of blue water resources (surface and groundwater), green water footprint refers to consumption of green water resources (rainwater) and grey water footprint refers to pollution and is defined as the volume of freshwater required to assimilate the pollution loads of given natural background concentrations and existing ambient water quality standards (EarthScan 2011).

If water footprint is accounted for in production or the impacts it will cause to the environment, a nation's real water demand could be very much higher than the total internal water withdrawals, if the product is imported. The reverse may also be true as a nation's water demand may be lower than suggested by internal withdrawals if water intensive products are exported. The water footprint of a nation can be affected by the amount and type of consumption, consumption patterns, climate and agricultural practices. To illustrate, United States and Canada have large water footprints due to the amount of meat and industrial products consumed within their countries, while Malaysia's water footprint is big due to low crop yields (refer **Figure 3.9**).

Nonetheless, Malaysia has yet to implement a comprehensive national water footprint programme. Malaysia's average water footprint is approximately 2,103 $m^3$/year per capita, which is higher than the global average of 1,385 $m^3$/year per capita (Water Footprint Network), indicating that Malaysia is a net exporter of water to other countries. Taking into account of the virtual water used to grow crops and to manufacture products, Malaysia can truly account for its water resource.

The export of water intensive crops can constrain the country's water resources while importing such crops may be beneficial by not having to account for the grey water footprint (pollution) the producer country experiences, but has not priced into the production cost. Thus as water becomes ever scarcer, the true value of products made using water, may have to take into account the actual water cost required to produce it.

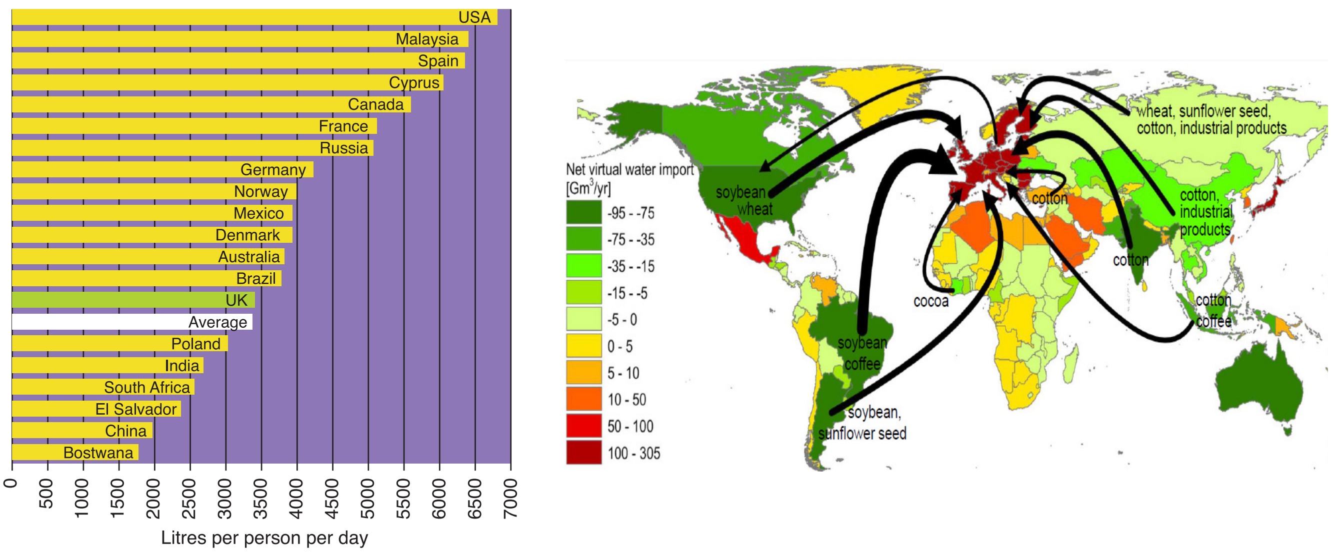



Figure 3.9 Comparative Water Footprint of Nations

Photo 28: Agriculture contributes to high water footprint for Malaysia

Photo 29: The cost of water is often not factored in throughout the product lifecycle

Photo 30: Indirectly virtual water is exported to other countries

Note: Figure 3.10 provides a broad tentative framework for a national water footprint programme in the country. As the concept is quite new, Malaysia's capacity in water footprint accounting is still low and requires further research and development as well as capacity building in the concept and applications.

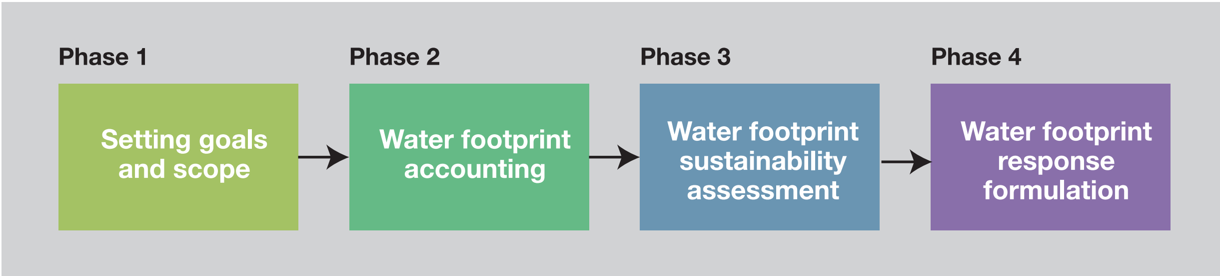



Figure 3.10 Framework for Water Footprint Implementation

## 3.16 WASTEWATERTREATMENT TECHNOLOGY

Wastewater has long been treated as a waste product to be discharged into the waterways where it eventually causes pollution. Nevertheless, in reality, wastewater from industrial processes, sewage treatment plants and irrigation outflows, may provide a valuable source of water, energy, organic matter, nutrients and minerals. These compounds can be recovered for safe use and to obtain high quality products. Current wastewater treatment technologies include the following:

a) **Sand filtration:** effective for removal of particulate matters such as clay and silt, micro-organisms and precipitates of organics and metal ions;

b) **Activated carbon:** used to remove natural organic matter and colour, pesticides, taste and odour forming compounds and algal toxins;

c) **Ozonation with activated carbon:** pesticide removal. However,thecost can be high and may produce harmful by-products;

d) **Photochemical treatment:** e.g. ultra-violet;

e) **Chlorination:** disinfectant to remove bacteria and pathogens. However, the cost can be high and may produce harmful by-products;

f) **Chloramination:** involves dosing a controlled amount of ammonia post chlorination; and

g) **Membrane technology:** a technology that has matured in the past few years, enabling filtration of colloidal materials and pathogenic organisms, however the downside is that membranes are prone to fouling.

As such, the current STI looks at resource recovery as a viable option through wastewater recycling, biosolids management and biogas recovery. Research avenues that can be developed include:

- Improve efficiency of current treatment plants such as energy savings and reduction in waste generation
- Removal of organic compounds from wastewater and the economising of these resources
- Identification of current and future pollutants in wastewater in anticipation of treatment options
- New treatment options and systems
- Minimisation of corrosion of pipe works and deposition of solids from process water
- Economising of wastes, e.g. bioeffluent, biosolids and biogas

Photo 31: Energy efficiency and reuse of waste water recycling have potential for development

Photo 32: Biosolids for nutrient recovery and as fertilisers

Photo 33: Improvements in wastewater treatment and monitoring is needed

## 3.17 BIOEFFLUENT

Industrial and municipal wastewater treatment plants often contribute large amounts of nutrient into the river system. The challenge now is to develop technologies to allow wastewater treatment operators to economise on their operations while reducing generated waste and improve the water quality of treated discharge, in effect turning such facilities into Resource-recovery Plants. Filtration technology to remove unwanted substances from wastewater is considered a matured industry with various filters available on the market. A summary of available technology is shown in **Table 3.5**:

Table 3.5 Typical Filtration Technologies

| | |
|---|---|
| Microfiltration | Typical pore size: 0.1 microns<br>Pressure: Very low<br>Removes: Viruses, proteins and other organic molecules<br>Does not removes: ionic particles |
| Ultrafiltration | Typical pore size: 0.01 microns<br>Pressure: Moderately low<br>Removes: Bacteria, large viruses<br>Does not removes: Small viruses, protein molecules, sugar and salt |
| Nanofiltration | Typical pore size: 0.001 microns<br>Pressure: Moderate<br>Removes: Toxic and unwanted bivalent ions |
| Reverse Osmosis | Typical pore size: 0.0001 microns<br>Pressure: Very high<br>Removes: Only economically feasible large scale method to remove salt from water |

Hence, wastewater recycling for non-potable use is one avenue for treated effluent reuse. While there is still a social acceptance issue for potable use of treated wastewater, non-potable use for treated wastewater is an avenue that can be developed further. Typical non-potable reuse can include:

- Agriculture irrigation (paddy irrigation, crop watering).
- Municipal reuse (public space irrigation, toilet flushing and public cleaning, firefighting water).
- Industrial reuse (cooling systems, process water, construction site use).

## 3.18 BIOSOLIDS MANAGEMENT

Centralised sewage treatment plants using biological treatment to decompose organic components in wastewater is effective in breaking down organic substances but still leaves behind nutrient rich end product (biosludge). Tertiary treatment is available to remove substances like nitrogen and phosphorus through biological and chemical methods.

A plant in Oregon, USA utilises technology in reducing the phosphorus pollution from wastewater treatment plants and reuses the recovered nutrients as fertilisers. Treatment plants that uses biological nutrient removal produced concentrated phosphorus in their sludge stream resulting in the build-up of 'struvite' along piping, pumps and valves. This build-up increases maintenance costs and shorten facility lifespan. Technologies have been developed to remove the sludge which can be processed into fertilisers. The process utilised at the Oregon plant also uses 40% less alum for phosphorus removal while recovering 85% of phosphorus in the centrate, the residual solid matter after dewatering of the wastewater SPAN.

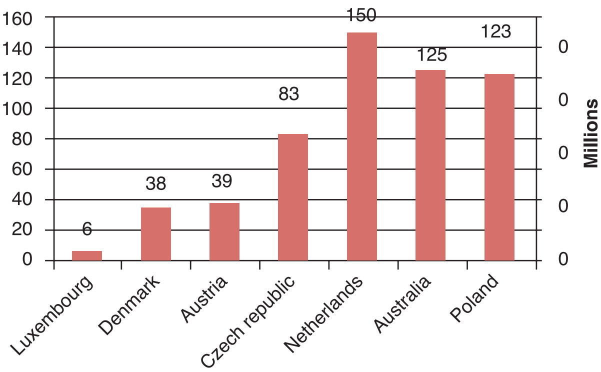
Biosolids are rich in nutrients such as nitrate, nitrite and phosphorus making them ideal candidates for use as fertilisers or soil amendments after processing to remove any impurities. Another method besides treatment of biosolids or its use as compost is to convert the biosolids directly into energy (waste to energy) through biogassification. Research into the reuse of biosolids as fertilisers were successfully conducted by a Universiti Putra Malaysia (UPM) research team which indicates that treatment sludge from STPs is effective and safe to be used for crops.

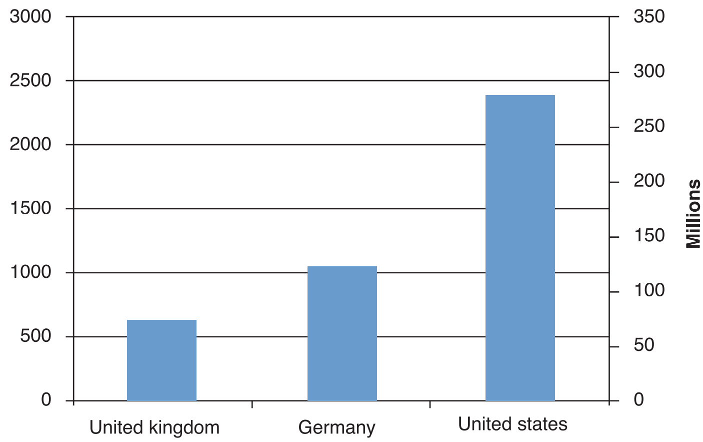
## 3.19 BIOGAS CAPTURE

The idea to trap biogases from wastewater treatment processes is not new and existing technologies include covered lagoons, mixed digesters, plug flow digesters and upflow sludge blanket digesters. Currently, most STPs flare the biogases produced rather than utilising it as a resource. However as with other resource recovery technology associated with wastewater treatment, much is needed to address issues of high capital and energy costs, limited generation capacity compared to traditional power plants and new technologies required to process feed stocks to improve efficiency.

Biogas capture provides benefits in the form of providing clean-burning, renewable biofuels to replace traditional fuels (reducing methane, sulphur dioxide, nitrogen dioxide, carbon dioxide and methane emissions), is carbon neutral, eliminates harmful pollutants from the discharge and improve air quality. At present there are plans to adopt biogas for use in plant electricity generation by IWK at several of their regional plants at Jelutong STP, Pantai STP and Bunus STP. There are existing plants tha

Table 3.6 Electricity Generated from Sewage Biogas in Selected Countries in 2009




## 3.20 INTEGRATED URBAN WATER RESOURCES MANAGEMENT

***Growth of cities and urban flood management***

Water as a feature in urban setting has not been much valued; the main aim of city developments were to channel water out of urban areas (Malaysia's current population in urban areas is approximately 71%, refer **Figure 3.11**) to flush out wastes and to prevent flooding. Development of waterways in cities such as Kuala Lumpur has focused on structural measures such as river diversion and channelising rivers. This method has limitations when the rainfall is heavy and where urban runoff ultimately overwhelms the drainage capacity to discharge floodwaters, leading to urban floods.

As cities continue to grow, a paradigm shift is required to re-look at the growth of cities and urban areas especially on the management of urban water systems and floods and their impacts on downstream environments. Stormwater runoff management is one aspect that has already been looked at with the introduction of the *Manual Saliran Mesra Alam* (MSMA) by the DID, which covers a whole range of design management concepts such as the use of pervious surface to allow for infiltration of stormwater into the ground, flood retention ponds, erosion and sediment control systems, etc.

The utilisation of urban run-off as an alternative water source in urban areas is one area that has not been fully studied and implemented in the country. Singapore through the long-term clean-up of the Kallang River and the construction of the Marina Barrage to serve as an urban water catchment are examples of capturing all possible water resources to meet its water needs.

In terms of Water Sensitive Urban Design (WSUD), common Best Management Practices (BMPs) include:

- Use of pervious surface for groundwater infiltration.
- Green roof for water capture and retention.
- Artificial wetlands to act as pollutant removal systems.
- Ecological engineered rivers.
- Sustainable urban drainage systems.
- On-site detention ponds.

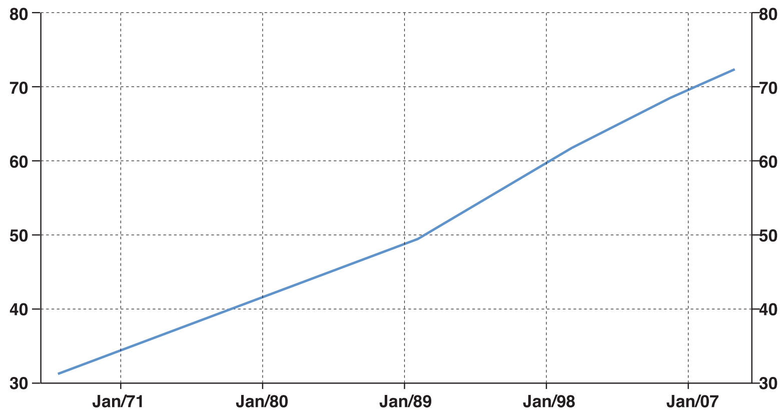



Figure 3.11 Urban Population (%) within Malaysia

Photo 34: Water sensitive design for better runoff management

Photo 35: Constructed wetland can help in pollution control

Photo 36: The Marina Barrage provided freshwater storage sourced from urban stormwater

## 3.21 COMMERCIALISATION OF WATER TECHNOLOGY

The World Intellectual Property Organisation (WIPO), the body overseeing the international patent filing system, has revealed that patent applications for 'green technology' has increased more than 100% over the period of 2000 to 2008, indicating an increasing trend in investments in the sector (Jenny & Chris 2009). Malaysia should seek to study the potential of developing its water-based sector as it is potentially a large market, especially as water resources are growing scarce. This would include development of the entire supply chain from R&D, patenting and Intellectual Property Rights (IPR), commercialisation, manufacturing and exports of goods and services in the water sector. While Malaysia has developed some form of markets for water sector in the utility sector, the potential for larger growth is still there.

An example of a success story is the Netherlands, which has developed its water management skills due to the underlying geography (most of the country is under mean sea level) which has resulted in a robust growth in its flood management, reclamation and dredging technology, water infrastructure, water supply and sewerage and adaptations to flooding. Their success has been translated into a large industry that spans the globe with Dutch firms exporting their expertise worldwide.

Singapore, too, has identified water and environment technology as key growth sectors since 2006 and is investing heavily on R&D in water solutions. The National Research Foundation (NRF) has committed $470 million in promoting R&D in the water sector. For a water resource poor nation, it has managed to position itself as a hydro-hub, funding promising research projects and enticing water-related companies to set up businesses in their country (100 international and local water companies and 25 research centres) (Singapore International Water Week (SIWW)). The SIWW, for instance, is a global platform to share and co-create innovative water solutions through collaboration between global water industry players. Events hosted include the Water Expo, Lee Kuan Yew Water Prize, Water Leaders' Summit, Water Business Forum, Water Convention, Industrial Water Solutions Forum, TechXchange and SIWW Water Utilities Leaders' Forum (SIWW). This yearly event is an industry in itself and generates both income and prestige for its host country.

It is also interesting to note that the World Toilet Organisation (WTO) is a well-renowned global non-profit organisation with the goal of improving sanitation conditions worldwide. It's founder, Jack Sim, started the Restroom Association of Singapore in 1998 to improve toilet sanitation and later founded the WTO in 2001 and World Toilet College (WTC) in 2005. Today the WTO has grown into an organisation with 151 member organisations working in 53 countries worldwide and its founder has been appointed as a Council Member to the World's Economic Forum Global Agenda Council for Water Security (Wikipedia 2015). This is the examples of the potential for being world leaders in the water resource and technology sector that Malaysia should invest in; seeing that water resource is abundant in the nation and potential for growth is good.

## 3.22 CAPACITY-BUILDING AND WATER KNOWLEDGE DEVELOPMENT

The development of Science and technology in the country will depends on the level of education and skills training of the country's young population, especially in the critical areas of Science and Mathematics. A current look at the state of education in Malaysia, in terms of science and maths skills, benchmarking with neighbouring countries in the Programme for International Student Assessment (PISA) survey, shows that Malaysia ranked below most of them.

When benchmarked against the 2009 scores, Malaysia had improved on mathematics mean scores but slipped in terms of reading and science scores (refer **Figure 3.12**). Results for all three areas were below the Organisation for Economic Cooperation and Development (OECD) mean scores. Similarly, Malaysia's performance in the Trends in International Mathematics and Science Study (TIMSS) has seen a decline over the years (2007 – 2011) for both maths and science. Lastly, the Times Higher Education World University Ranking revealed that not a single university in Malaysia has managed to be placed within the 400 top universities in the world. Within Asia, only Universiti Kebangsaan Malaysia (UKM) managed to be placed 87$^{th}$ among 100 universities, in comparison with Singapore, being placed 2$^{nd}$ (National University of Singapore) and 11$^{th}$ (Nanyang Technological University) (The Times Higher Education World University Rankings).

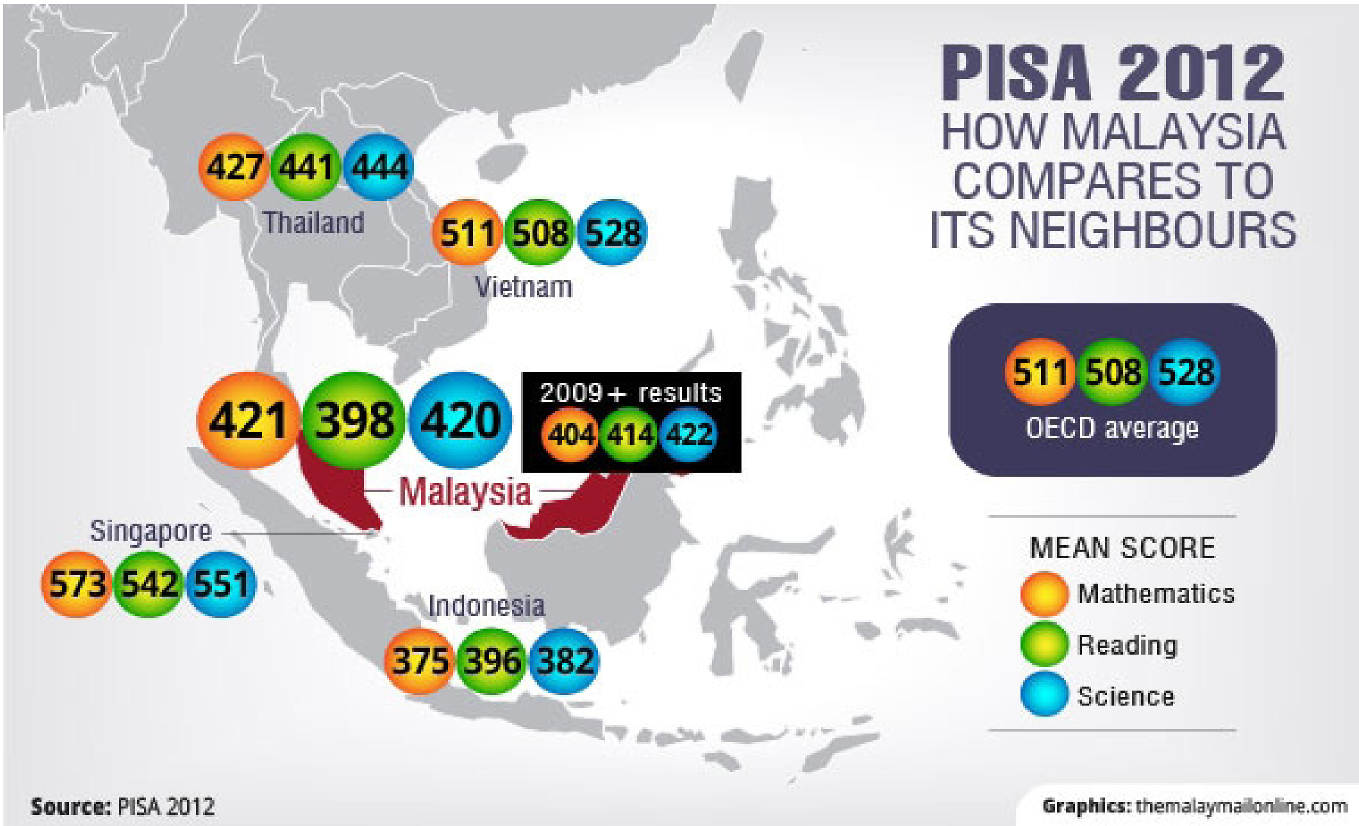



Figure 3.12 PISA 2012 Scores for Malaysia and Neighbouring Countries

Source: PISA 2012

Water-related education and environmentally related subjects are all integrated into the syllables, but there is still no single subject specifically on water management and environmental conservation in the Malaysian education system with exception of several tertiary institutions and water research centres/organisations (GeeBee University Finder). **Table 3.7** summarises some of their functions (the list of functions are by no means exhaustive but only the main functions related to water are tabled). These organisations serve to advocate and provide short-term skills training on various aspects of water and environmentally related applications.

Table 3.7 Major Institutions involved in Water Research and Development

| Institutions | Functions |
|---|---|
| National Hydraulic Institute of Malaysia (NAHRIM) | • Conduct basic and applied research on water such as water resources, river, coastal, geohydrology and water quality<br>• Provide support services to both the public and private sector in addressing water and its environment problems<br>• Act as the National Focal Point on water and its environment research by coordinating related national research and participating in bilateral and multilateral international research activities<br>• Provide advisory services on water and its environment matters in line with national interests |
| Malaysian Water Association (MWA) – Water Academy | • Provide institutional support for government initiatives towards development of quality workforce for global competitiveness/ liberalisation of water industry<br>• Provide integrated and accredited education and training for all stakeholders across the public and private divide of the water and wastewater sector<br>• As a strategic platform for collaborative research and innovations between academia and industry, local and foreign experts |
| Humid Tropical Centre (HTC) | • Promote collaboration among countries in the regions of Southeast Asia and the Pacific through technology and information exchange, education and science<br>• Increase scientific and technological knowledge about hydrological cycle, thus increasing the capacity to better manage and develop the water resources in a holistic manner |
| Water Research Alliance, Universiti Teknologi Malaysia | • Stimulate, encourage and enhance research programs, postgraduate studies and advisory and consultancy services in water research related areas e.g. applied science and engineering on water, solid waste management and recovery, wastewater treatment and recycling and design and construction of hydraulic structures, river basin management and engineering and coastal and lowland area engineering |

| Institutions | Functions |
|---|---|
| Association of Water and Energy Research Malaysia | • Conduct research and development in soft and hard research in water, energy and environment related fields in providing solutions<br>• Use evidence based approach in providing suggestions and ideas in enhancing water, energy and environmental clusters in achieving sustainable development in Malaysia and the world<br>• Publish independent reports and publications as guidance, solution and awareness materials for all stakeholders<br>• Play a vital role in achieving water and energy security as well as efficiency in utilising water, energy and environmental resources in Malaysia and the world<br>• Conduct seminars, workshops, awareness campaigns, training, etc.; in creating awareness and positive change on water, energy and environment related issues to all level of stakeholders<br>• To be a leading NGO in research and development in Malaysia and the world for the water, energy and environmental fields |
| Malaysian Water Partnership (MyWP) | • Provide strategic advice to the government and relevant stakeholders on water and water related matters with emphasis on adoption of IWRM principles and practices<br>• Promote greater awareness in IWRM among stakeholders<br>• Provide and disseminate synthesised knowledge and experience on BMPs in IWRM<br>• Foster interaction among its members by promoting cross sectional and multi-stakeholder dialogues at local, river basin, State and national levels to meet critical needs<br>• Provide support in capacity building and training programmes and activities related to IWRM<br>• Provide support for research and development initiatives related to IWRM<br>• Act as the focal point and coordinating centre for collaborative action with similar or related organisations |

| Institutions | Functions |
|---|---|
| Malaysian Hydrological Society | • Promote education and training<br>• Promote scientific research and study of hydrology<br>• Collaborate with other scientific organisations with similar objectives at national and international level including the advancement of hydrologic discipline.<br>• Disseminate information through publication of newsletters, journals and other mediums.<br>• Host, organise and participate in meetings, conferences for exchange of research findings, information and experiences |
| Akademi Sains Malaysia (ASM) | • Promote and foster the development of science, engineering and technology<br>• Provide a forum for the interchange of ideas among scientists, engineers and technologists<br>• Promote national awareness, understanding and appreciation of the role of science, engineering and technology in human progress<br>• Promote creativity among scientists, engineers and technologists<br>• Promote national self-reliance in the field of science, engineering and technology<br>• Act as a forum for maintaining awareness on the part of the government of the significance of the role of science, engineering and technology in the development process of the nation and for bringing national development needs to the attention of scientists, engineers and technologists<br>• Analyse particular national problems and identify where science, engineering and technology can contribute to their solution and accordingly to make recommendations to the government<br>• Keep in touch with latest developments in science, engineering and technology and identify those developments which are relevant to national needs and to bring such developments to the attention of the government |

| Institutions | Functions |
|---|---|
| Akademi Sains Malaysia (ASM) | • Prepare reports, papers and other documents relating to the national science, engineering and technology policy and make necessary recommendations to the Government<br>• Initiate and sponsor multi-disciplinary studies related to and necessary for the better understanding of the social and economic implications of science, engineering and technology.<br>• Encourage research, development, education and training of the appropriate scientific, engineering and technical manpower<br>• Establish and maintain relations between the Academy and overseas bodies having the same or almost similar objectives in science, engineering and technology as the Academy<br>• Advise on matters related to science, engineering and technology as requested by the Government from time to time |

While there are many institutions offering higher education in water education (refer **Table 3.7**), the nation requires a dedicated institute to train professionals as water managers. One suggestion is to set up **a National Water Education and Training Centre** to provide training to local stakeholders, institutional members, academia and communities. One example of an established centre of excellence is the UNESCO-IHE Institute for Water Education based in Delft, Netherlands. It is the largest water education facility in the world and is the only United Nations system authorised to confer accredited mater degrees (Environmental Science, Urban Water and Sanitation, Water Science and Engineering and Water Management). Hence, in having such a centre in Malaysia it will attract local and foreign water professionals from all over the world, and in the process, upgrade out skills and knowledge on and development of water management in the country.

Table 3.8 Water-Related Courses Offered by Local Institutions

| Institutions | Courses |
|---|---|
| Kuala Lumpur Infrastructure University College | Master in Civil Engineering - Water Resources Engineering (By Research)<br><br>Doctor of Philosophy (PhD) in Civil Engineering - Water Resources Engineering (By Research)<br><br>Bachelor of Technology (Honours) in Water and Wastewater |
| University Malaysia Sabah | Master of Science in Water Quality and Wastewater Management by Research<br><br>Doctor of Philosophy in Water Quality and Wastewater Management by Research |
| University Malaysia Sarawak | Master's Degree in Water Treatment Technology (By Research)<br><br>Master's Degree in Water Resource Management (By Research)<br><br>Master's Degree in Integrated Water Resource Management (By Research)<br><br>Master Degree in Environmental Science (Land Use and Water Resource Management) (By Coursework)<br><br>PhD in Water Treatment Technology (By Research)<br><br>PhD in Water Resource Management (By Research)<br><br>PhD in Integrated Water Resource Management (By Research) |
| Universiti Sains Malaysia | Master of Science in Water Resources Engineering (By Research)<br><br>Doctor of Philosophy (PhD) in Civil Engineering - Water Resources Engineering (By Research)<br><br>Bachelor of Civil Engineering Programme - Water Resources Engineering |
| Universiti Teknologi MARA | Master of Science in Water Resources Engineering By Coursework<br><br>Doctorate of Philosophy in Civil Engineering (Water Resource Engineering) By Research<br><br>Doctorate of Philosophy in Civil Engineering (Waste water and Environmental Engineering) By Research<br><br>Bachelor of Engineering (Honours) Civil (Water) |
| Open University Malaysia | Master of Environmental Science (Integrated Water Resources Management) |
| Universiti Tun Hussein Onn Malaysia | Master in Civil Engineering - Water Resources Engineering (By Research) |

| Institutions | Courses |
| --- | --- |
| University Putra Malaysia | Master of Science in Water Resources Engineering by Research |
| | Master of Science in Soil and Water Engineering by Research |
| | Master of Science in Environmental Systems and Processes Marine and Fresh Water Ecosystem by Research |
| | Master of Water Engineering (Without Thesis) |
| | Master of Science (MSc) in Soil Conservation and Water Management by Research |
| | Master of Science (MSc) in Water Management (Without Thesis) |
| | Master of Science (MSc) in Natural Resource Policy - Water Resource Economics |
| | Doctor of Philosophy in Water Resources Engineering by Research |
| | Doctor of Philosophy in Soil and Water Engineering by Research |
| | Doctor of Philosophy in Natural Resource Policy (Water Resource Economics) |
| | Doctor of Philosophy in Environmental Systems and Processes Marine and Fresh Water Ecosystem by Research |
| | Doctor of Philosophy (PhD) in Soil Conservation and Water Management by Research |
| Universiti Teknologi Petronas | MSc in Civil Engineering - Water Resources Engineering (By Research) |
| | MSc in Civil Engineering - Waste Water Engineering (By Research) |
| | PhD in Civil Engineering - Water Resources Engineering (By Research) |
| | PhD in Civil Engineering - Waste Water Engineering (By Research) |

## 3.23 SUMMARY

This study has reviewed the water sector in terms of the challenges and issues that need to be addressed and the gaps that need to be filled in if it were to create new wealth opportunities in the country. Among the critical areas that require further development in terms of STI are as follows:

a) **Water Demand Management** – Malaysia is considered a water surplus nation, yet many States are finding it difficult to meet the water demand of its population. Water deficits have been recorded for Perlis, Kedah, Pulau Pinang, Selangor and Melaka, mainly due to the uneven distribution of water resources, increasing water stresses and uncertainties caused by global climate change.

However, the supply-side water management, which has long been practiced, may no longer be adequate to meet growing demand. To illustrate the intensity of the growing needs, the average Malaysian uses approximately 226 litres of water per day as compared to the United Kingdom (150 L/person/ day), Singapore (151 L/person/ day) and Africa (47 L/person/day). The problem is further compounded by high rates of NRW which was recorded as high as 61%, resulting in wasted resources. Thus, focus for STI should be in areas of development of alternative water resources, improving water demand management, ensuring water efficiency and reducing NRW. In particular, sectoral water demand managementmust be a key focus, whereby agricultural water usage is the highest at 70%, industrial at 20% and the remaining is for domestic water use.

b) **Integrated Urban Water Resource Management** – The urbanisation of the country has reached 71%, indicating that more people are now living in cities than rural areas. The concentration of population, commercial and industrial activities within the dense confines of modern cities has resulted in ever greater water demand while increasing generation of water pollution.

Apart from that, the risk and vulnerability of population to water stresses and water-related disasters also increases within the confines of cities. Thus, IUWRM seeks to change the impact of urban development on the natural water cycle by closing the water loop through efficient use of existing water resources to derive maximum economic benefit and equitable water among the various sectors. STI will focus in areas of improving water infrastructure, adoption of water sensitive designs, stormwater management, water pricing, addressing water pollution and better management of watersheds.

c) **Water Recycling** – Maximising existing water resources can be carried out through the utilisation of wastewater which has long been treated as waste products. In industries, these measures are common practices to reduce operational costs and discharge of wastewater e.g. zero discharge. The biggest user of water is the energy sector which requires large quantities of water for cooling purposes followed by the food and beverage industry.

One of the most promising sectors for water recycling is in wastewater treatment e.g. STPs which has thus far not capitalise on turning their waste products into wealth. The reuse of bioeffluent, biosolids and biogas is an untapped industry and could be a driver for greater water and energy efficiency. For residential water recycling, the use of greywater has not been developed, while for potable water, recycled water could potentially supplement water resources, as some other countries worldwide has begun to tap into it.

d) **Groundwater Development** – Groundwater resources for Malaysia remains largely untapped, comprising only 3% of total water abstracted. Kelantan remains one of the few States to develop their groundwater resources while recent private initiative in Perak did not bore fruit.

The development of groundwater reserves is thus a sector that should be studied further not only of its abstraction potential but also as water banks through groundwater recharge systems. STI opportunities abound including needs for groundwater mapping, sustainable groundwater management, development of abstraction technology and supply systems, groundwater pollution prevention and resolving of trans-boundary aquifer utilisation.

e) **Rainwater Harvesting** – Rainwater harvesting is one of the alternative water sources, maximising utilisation of stormwater which would otherwise have ended up unused. Rainwater harvesting has been adopted in Malaysia since the drought of 1998 which saw water rationing in the Klang Valley. Eventually the Ministry of Housing and Local Government introduced a Guideline for Rainwater Collection and Utilisation System (1999) and was further entrenched when the National Council for Local Government approved new by-laws for mandatory rainwater harvesting systems (RWHS) for residential property and government buildings.

Although there are requirements for such systems, the uptake of the technology has not been encouraging, likewise private sector adoption has been low. One major issue is integration of RWHS into the local water supply infrastructure whereas restrictions are placed on using rainwater as direct water supply. Incorporating dual plumbing systems may be the way forwards by separating water usage for potable (kitchen and bathing) and rainwater (toilet flushing and gardens). There are still challenges to overcome for wide spread use of the technology such as lowering costs, improvement in system design and improving its efficiency in high-density buildings or regional systems.

f) **Water Footprint Reduction** – Production of goods (agriculture and manufacturing) entails various processes that consume water throughout the supply chain, thereby resulting in the actual cost of water not being factored into its economic costs. This water cost is often referred to as virtual water. For Malaysia, the country's water footprint ranks as one of the highest among the world (second only to the United States), indicating that we utilise large amounts of water in the production of goods which are then exported out to other countries.

The implication is that we may be using more water than we can afford as well as under-pricing our goods indicates a need to have a proper water accounting for the country as part of water resources management planning. Reducing the population's water footprint is another concern in terms of maintaining water sustainability for the nation, as Malaysia's water demand is high and resource use inefficient. Another aspect that needs further study is in the development and implementation of PES which seeks to monetise our water resources to ensure its continued preservation and conservation.

The opportunities to develop STI in the water sector are many, as shown in the review and summarised in **Table 3.9.** These opportunities should be developed further by the various research institutes and institutes of higher learning prior to commercialisation of projects that could be derived from them in the short, mid-term and long-term time schedules.

Table 3.9 Science, Technology and Innovation Opportunities (2013 – 2050)

| | **Development of STI Opportunities** | | |
|---|---|---|---|
| | **2013 – 2020** | **2020 – 2035** | **2035 – 2050** |
| Water Supply and Demand Development | • Optimisation of existing water resources<br>• Water demand management programmes<br>• Study the availability and potential exploitation of alternative water sources<br>• NRW reduction in agriculture and domestic sectors | • Development of alternative water sources e.g. groundwater, rainwater harvesting<br>• Develop water efficient utilities and services<br>• Water pricing evaluation | • Sustainable management practices and technology adoption<br>• Integration of all water resource options i.e. atmospheric, surface, groundwater and seawater into the supply scheme |
| Water Pollution Control | • Research and development of non-point source pollution control<br>• Revision and re-evaluation of existing pollution standards<br>• Implementation of IRBM for all major river basins | • Implementation of non-point source control systems<br>• TMDL adoption pilot to major stressed rivers<br>• Automated water monitoring system network | • Research management of novel pollutants (EDC, PCPPs, POP).<br>• Trans-boundary water pollution management |
| Ecological and Water Resource Sustainability | • Research into implementation of environmental flow standards<br>• Basic research/ capacity building in ecological management<br>• Development of mechanisms/ markets to assess and regulate ecosystem services<br>• Intensifying IRBM programmes | • Implementation of environmental flow management<br>• Payments for ecosystem services implementation<br>• Water footprint assessment for the country | • Water resource sustainability developments<br>• Water security<br>• Climate change adaptations adoptions |

| | Development of STI Opportunities | | |
|---|---|---|---|
| | 2013 – 2020 | 2020 – 2035 | 2035 – 2050 |
| Advanced Water and Wastewater Treatment Systems Development | • Research and develop new water treatment technologies<br>• Improve efficiency and performance in existing sewage treatment<br>• Research bio-solids and sludge management technologies | • Pilot projects and efficiency assessment of technology<br>• Combined sewer/ stormwater systems adoption | • Commercialisation of technology and services<br>• Industrial implementation of bioeffluent/ biosolids/ biogas systems |
| Water and Green Growth | • Needs assessment on developing green industries/ technologies<br>• Basic research and identifying potential green tech adoption<br>• Set up water organisations to spearhead water sector development | • Water sensitive designs<br>• Development of basic green industries/ sectors<br>• R&D labs/ clusters<br>• Pilot projects on water infrastructure and green technology | • Development of green based economies and technologies<br>• Integrated and smart townships |
| Capacity-building and Water Knowledge Development | • Relook at current curricula on water resource management at all levels<br>• Improvement in water governance<br>• Needs assessment for all water sectors | • Develop capacity of water managers<br>• Set-up water innovation centres and research labs<br>• Identify key technologies for local development<br>• Key funding for R&D | • Development of Hydro Hub in Malaysia<br>• Set-up water/ green industries in the country<br>• Export of expertise and skilled workers |

# CHAPTER 4
## ENERGY

There are two main kinds of non-biological energy used in Malaysia. One is electrical energy (electricity) generated by power plants running on coal and hydroelectric plants running of fast-flowing water. The other kind is energy from combustion of petroleum in internal combustion engines such as motorised vehicles. The key environmental issue in energy production and management is how to quickly replace fuels such as coal and petroleum, which produce carbon dioxide (a major greenhouse gas) with energy that can be generated without producing carbon dioxide such as solar energy.

Alternatively, employing 'renewable' fuels like plant biomass (e.g. wood and plant residues) would have a zero carbon footprint because the output of carbon dioxide from recently-dead biomass can be balanced by new plant growth (hence does not add carbon dioxide to the atmosphere on a net basis) unlike fossil fuels which is ancient biomass like coal and petroleum that took many millions of years to make. There are also issues over the cost and security of energy supplies.

Malaysia's primary commercial energy supply consists of four fuels namely oil, gas, coal, and hydroelectric. A major share of the current supply mix is heavily dependent on fossil fuels with only a 2.5% contribution from hydroelectric in year 2010 and none from non-hydroelectric renewables (see Figure 4.1). A similar trend is observed in the electricity generation mix (see TABLE 4.1 and Figure 4.2)—however a key observation is that there is no share of renewables reported in 2010 or projected to 2030 while nuclear energy has been planned for deployment.

In spite of that, the Five-Fuel Diversification Policy 2001 recognises non-hydroelectric renewable energy as a fifth fuel in the nation's power generation mix, in which one of the initiatives is the SREP (2001–2010) the initiated program, to encourage small private power generation projects using renewables. The National Green Technology Policy 2009 serves to promote green technologies, cogeneration, and renewables in power generation. More recently, in 2011, the RE Act is legislated mainly to implement a Feed-in-Tariff (FiT) scheme for renewables. In 2011, the National Biomass Strategy 2020 is formulated to promote the use of biomass waste for biofuels (Agensi Inovasi Malaysia, 2011).

Malaysia possesses substantial hydroelectric resource, which is by far the largest renewable energy type deployed in the country. Large hydroelectric dams are in operation in West Malaysia such as in Temenggor, Perak and Kenyir, Terengganu. Moreover, the ASEAN Power Grid provides a potential ready platform for harnessing use of hydroelectric power (Mohamed 2009; Hasan, 2009a).

Potential non-hydroelectric renewable energy resources in Malaysia mainly include biomass, biogas, and solar including waste-to-energy sources. Energy generated from renewables is environmental friendly because it not only reduces greenhouse gas emissions but eliminates pollution from agricultural wastes since a significant proportion of renewables utilizes such materials. Past initiatives include the two UNDP–GEF-supported projects, namely Biomass-based Power Generation & Co-generation in the Malaysian Palm Oil Industry (BioGen) project (2002–2010) and the Malaysia Building Integrated Photovoltaic (MBIPV) (2005–2011) project. However, their overall achievement resulted in only 45.9 MW connected to the national grid compared to the 350 MW target for RE under the Ninth Malaysia Plan (2006–2010) (Haris 2010b; Hasan, 2009a).

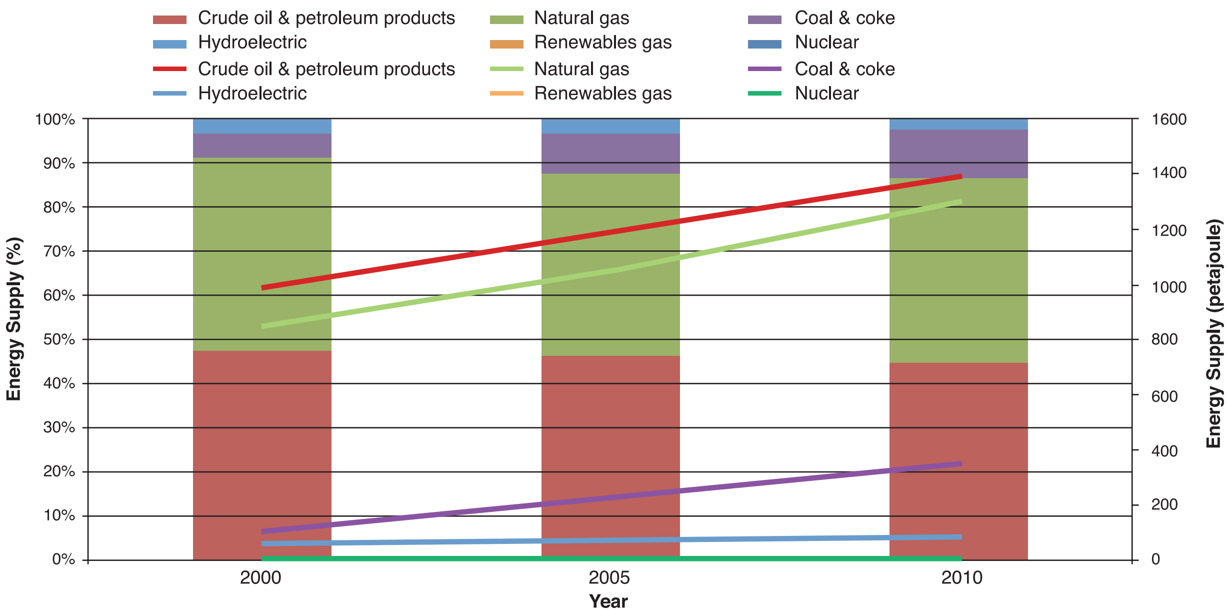



Figure 4.1 Malaysia: Primary commercial energy supply by source (1980–2010)

Source: Chin *et al.* 2013; Economic Planning Unit (EPU) 2010

Note: Energy supply refers to the supply of commercial energy that has not undergone a transformation process to produce energy. Natural gas excludes flared gas, reinjected gas, and exports of liquefied natural gas (LNG).

Table 4.1 Malaysia: Fuel Mix for Electricity Generation (2010-2030)

| Fuel type | Electricity mix (%) | | | |
|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2030 |
| Natural gas | 42.8 | 45.7 | 21 | 0.6 |
| Coal | 52.4 | 50 | 74.8 | 44.4 |
| Hydro | 4.8 | 4.3 | 4.1 | 4.8 |
| Oil/Petroleum products[a] | 0 | 0 | 0 | 0 |
| Renewables (non-hydro) | 0 | 0 | 0 | 0 |
| Nuclear | 0 | 0 | 0 | 50.3 |

Source: Chin *et al.* 2013; Energy Commission/Suruhanjaya Tenaga Malaysia, 2012

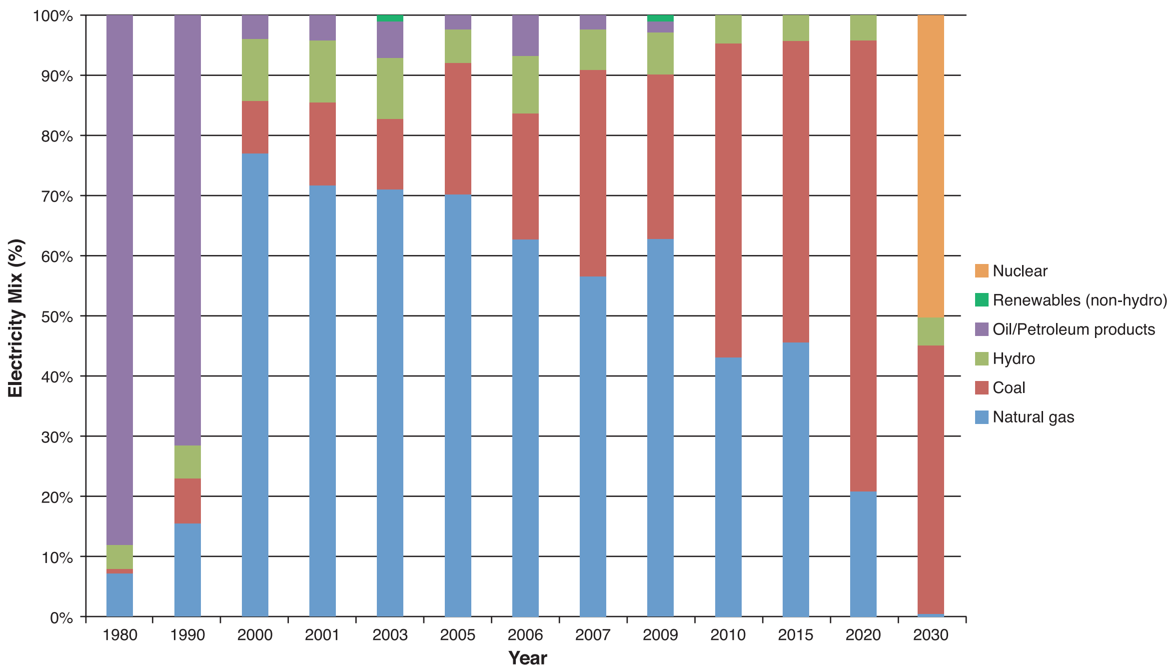



Figure 4.2 Malaysia: Fuel mix for electricity generation (2000-2030)

Source: Chin et al.2013; Energy Commission/Suruhanjaya Tenaga Malaysia2012

The current installed electricity generation capacity of renewables is relatively dismal at less than 1% (equal to 65 MW) of the nationwide total, mostly from biomass plants in Sabah SEDA Malaysia, 2012). Major factors for a low uptake of RE are due to: (1) uncertain biomass supply and cost; and (2) high capital expenditures with long payback periods due to a low electricity tariff for generation from renewable energy under the then SREP program.

Contribution of renewables to the country's electricity generation mix is expected to grow with the implementation of FiT under the RE Act 2011. The FiT scheme allows companies and individuals to sell electricity generated from renewables at a fixed premium price for a specific duration to public utility companies such as Tenaga Nasional Berhad (Haris 2010a). It is noteworthy that the FiT applies to grid-connected electricity generation only.

A regulatory framework has been established under RE Act 2011 through the Sustainable Energy Development Authority (SEDA) with clearly defined roles for the regulators and power producers. Moreover, dedicated funding is available to top-up the FiT rates for renewable power producers through the RE Fund administered by SEDA. Such initiatives support policies for reducing a dependency on fossil-fuelled power plantsand importantly to reduce carbon emissions. RE Act 2011 particularly FiT is expected to help achieve a national target of 11% (or 2080 MW) contribution from RE in the generation mix under the 11th Malaysia Plan (2016–2020) (see **Table 4.2**).

Table 4.2 Malaysia National Renewable Energy (RE) Targets

| Year | Cumulative RE Capacity (MW) | RE Power Mix (%)[a] | Cumulative $CO_2$ avoided (Mt) |
|---|---|---|---|
| 2011 | 73 | 0.5 | 0.3 |
| 2015 | 985 | 5.5 | 11.1 |
| 2020 | 2,080 | 11 | 42.2 |
| 2030 | 4,000 | 17 | 145.1 |

Note: Power mix is calculated as a ratio to peak demand.

Source: Sustainable Energy Development Authority (SEDA) Malaysia, 2012

## 4.1 RENEWABLE ENERGY OPTIONS

There is considerable potential in harnessing and further developing waste-to-energy options for producing bioenergy forms of renewable energy in Malaysia. As such, this chapter focusses on the STI opportunities for energy generation from the wastes of lignocellulosic biomass, palm oil mill effluent, and municipal solid waste. (The term "lignocellulosic biomass" refers to the main building blocks of plant matter, i.e. lignin, cellulose, and hemicellulose.)

In addition, STI opportunities for energy production from small hydropower and the potential for developing a sustainable large scale national solar photovoltaic industry are also presented. While some of these may not entirely represent novel STI efforts, it is however felt that in meeting the national 2080 MW renewable energy target by 2020, they need to be continuously studied for improved support by a systematic uptake of R&D programs in tandem with commercialisation and marketing efforts, which are aspects in line with the aspirations of the Mega Science Framework Study. The chapter considers the potential for nuclear energy generation, which is arguably GHG emissions-free, particularly by using thorium-based technology as well as various ongoing energy efficiency and conservation measures that ought to be further intensified in going forward.

## 4.2 ENERGY PRODUCTION FROM SECOND-GENERATION BIOETHANOL

### 4.2.1 PROSPECTS FOR SECOND-GENERATION BIOETHANOL IN MALAYSIA

Second-generation bioethanol, which is derived from biomass offers greater promise in replacing fossil fuels than does first-generation bioethanol, which is derived from edible sources, because the former obviates competition with human food supply. In addition, feedstock for second-generation bioethanol is more abundant than first generation bioethanol, which is based on food crops.

Thus, utilising cellulosic biomass would obviate the controversial competition with food production for land, water, and other resources. A major application involves blending bioethanol with gasoline (petrol) for transportation fuel. Compared to biodiesel, the Malaysian market for bioethanol is potentially much larger since a much higher proportion of our vehicle fleet runs on gasoline (Tye *et al.* 2011). Several studies by Malaysian researchers are available on this subject (Goh *et al.* 2010; Goh & Lee 2011).

### 4.2.2 ADVANTAGES AND BENEFITS OF BIOETHANOL

In principle, the use of biomass-based ethanol as an alternative energy source to fossil fuels can potentially reduce Malaysia's GHG emissions, particularly because fossil fuels make up the largest proportion of Malaysia's primary energy supply and electricity generation mix (EPU 2010). Furthermore, it has been a traditional practice for farmers in rural areas to burn biomass residues openly, while major plantation and mill operators are known to use such residues as fuel to generate steam—both activities of which result in GHG emissions. Thus using biomass to produce ethanol lends greater potential to reduced emissions (Goh & Lee 2011). In addition, ethanol can reduce particulate emissions in compression-ignition engines because it is an oxygenated fuel besides reducing toxic emissions such as oxides of nitrogen and sulphur ($NO_x$, $SO_x$)(Tye *et al.* 2011).

## 4.3 FEEDSTOCK AVAILABILITY

Large quantities of lignocellulosic biomass are available in Malaysia with suitable characteristics and properties as potential feedstock for producing bioethanol (Goh & Lee 2011). These biomass sources include: (1) agricultural waste, e.g., oil palm, rice or paddy biomass, and sugarcane; (2) forest residues, e.g., wood wastes and straw from the pulp and paper industry and logging activities; and (3) municipal solid waste (Goh *et al.* 2010; Tye *et al.* 2011). In terms of volume, biomass from the palm oil sector accounts for 85.5% of the total biomass share in Malaysia, while the remaining sources are mainly wood (3.7%), rice husks (0.7%) and sugarcane (0.5%) (Ahmad *et al.*, 2011).

## 4.4 TECHNICAL CHALLENGES

The process technology involved in producing second-generation bioethanol is capital intensive at the early stages. In particular, at the pretreatment stage to solubilise the hemicellulose, the lignocelluloses have to be broken down into sugars by a combination of expensive physical, chemical, and enzymatic processes for subsequent fermentation to produce ethanol (Tye *et al.* 2011; Hendriks & Zeeman 2009).

## 4.5 ENERGY PRODUCTION FROM INTEGRATED BIOGAS RECOVERY AND MICROALGAE CULTIVATION IN PALM OIL MILL EFFLUENT TREATMENT

### 4.5.1 PROSPECTS

There is potential in treating POME to simultaneously recover its gas emissions and culture microalgae for energy production besides solely applying traditional wastewater treatment technologies to meet regulatory discharge limits. The recovered biomethane can be used as fuels for electricity and heat generation subject to appropriate treatment and upgrade to suitable quality. The cultured microalgae can be utilised as raw material to produce the biofuels of biodiesel and bioethanol. Figure 4.3 shows a conceptual framework for such integrated biogas recovery and microalgae cultivation in palm oil mill effluent (POME) treatment with the goal of producing so-called third-generation bioenergy.

### 4.5.2 ADVANTAGES AND BENEFITS

Such a strategy augurs well with rising global need for environmentally sustainable practices since the biogas recovered and the biofuels produced are low-carbon renewable energies that promote reduced environmental impact of pollution and emissions. In particular, unrecovered methane emissions from POME that escape to the atmosphere may contribute towards greater global warming and climate change, because methane is a more potent greenhouse gas that has 72 times the global warming potential of $CO_2$ measured over 20 years and 21 to 25 times over 100 years (IPCC 2007).

This problem has been exacerbated by an increasing number of palm oil mills in Malaysia from just about 10 mills in 1960 to 410 operating mills in 2008 (Wu *et al.* 2010), and oil palm has the largest agricultural plantation acreage and production in the country as evidenced in the comparison with other major crops in Table 4.3 (Department of Agriculture Malaysia 2009). A life cycle assessment study on Malaysian palm oil milling reveals that uncaptured methane emissions from POME contributes the highest environmental impact towards climate change in the country and is responsible in making the overall industry not environmental friendly (Subramaniam *et al.* 2008). In addition, the potential revenue from generating the bioenergy may be used to offset the cost of wastewater treatment and for environmental protection on a whole.

Table 4.3. Malaysia: Land Area of Major Crops Planting and Annual Production (2007)

| | Area of planting (million hectare) | Production (million ton) |
|---|---|---|
| Oil palm | 4.30 | 26.1 |
| Rubber | 1.23 | 1.12 |
| Paddy | 0.68 | 2.38 |

Source: Department of Agriculture Malaysia 2009

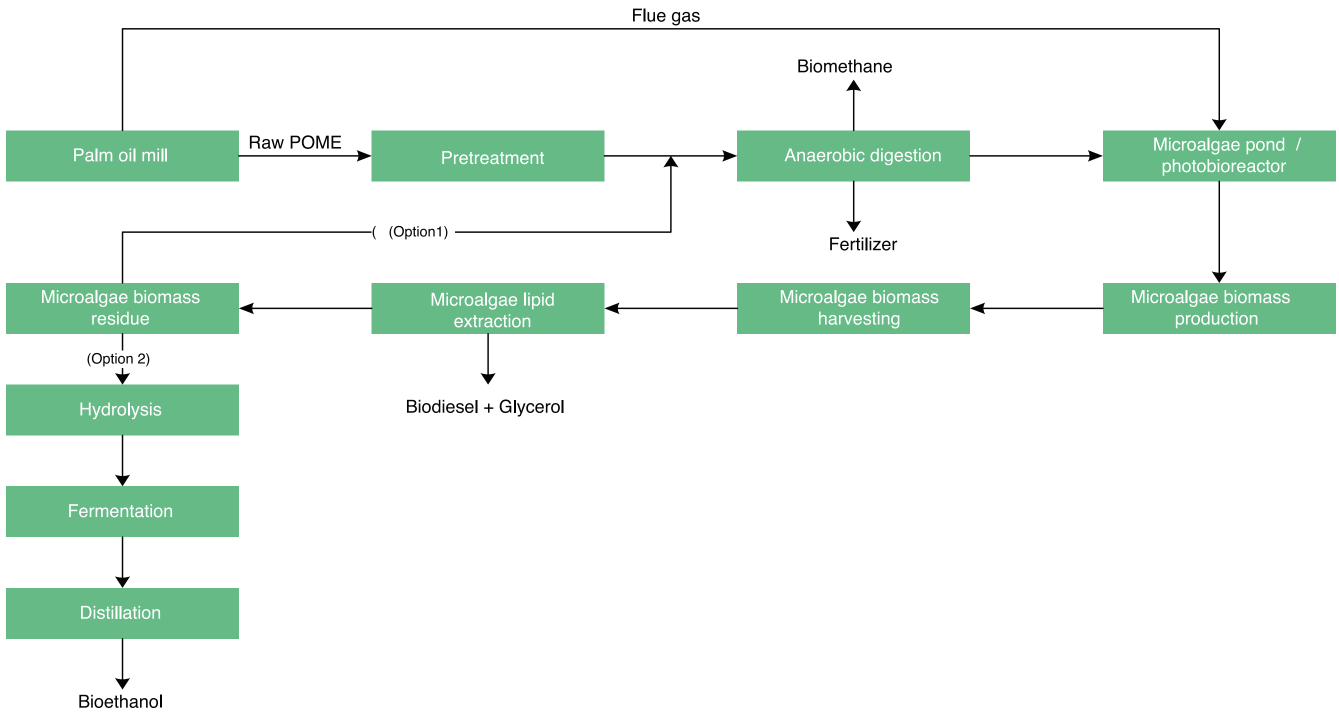



Figure 4.3 Conceptual framework for integrated biogas recovery and microalgae cultivation in palm oil mill effluent (POME) treatment for third-generation bioenergy production

Source: Lam and Lee 2011

Microalgae have been identified as a most feasible alternative feedstock for biofuels production based on its rapid growth rate at 100 times faster than terrestrial plants, its high lipid content with ability to synthesise a large quantity of oil (or neutral lipids), and lower requirement for land area (Khan *et al.* 2009). Multiple types of biofuels can be derived from microalgae including biodiesel from its lipid, bioethanol and biomethane from fermentation and anaerobic digestion of its biomass, respectively, and photobiologically-produced biohydrogen (Chisti 2007). Furthermore, algae enhances POME treatment by increasing the performance of organic material degradation, decreasing the energy demand for oxygen supply in the aerobic treatment stage, and improving the carbon dioxide balance (Kirkwood *et al.* 2003).

Therefore, a combination of POME wastewater treatment and renewable energy production can generate added value and competitive advantage to the palm oil industry besides reducing its environmental impact of air pollution and GHG emissions. An arising concern pertains to the competition that Malaysia is bound to face with many existing international players in microalgal biofuels. A particular challenge with respect to our local Malaysian situation is a lack of centralised collection for the biofuels produced.

### 4.5.3 TECHNICAL CHALLENGES TO PRODUCE BIOMETHANE FROMPOME

To convert the bulk of POME to biomethane, it is necessary to use anaerobic digestion in the first treatment stage due to a high level of organic matters in the wastes (Ab Aziz *et al.* under review). Conventionally, the treatment has been carried out using open pond or lagoon, i.e., open digesting tanks in Malaysian palm oil mills (Lam & Lee 2011). Nonetheless, valuable biomethane is released to the atmosphere in such systems and consequently leads to higher GHG emissions (Sulaiman *et al.* 2009).

An alternative for recovering biomethane from POME is to substitute the existing ponding or lagoon system with a closed anaerobic digester system. The replacement of such a covered lagoon can be done in a direct and cost effective manner by installing floating plastic membranes on open ponds. Consequently, released biomethane is captured and retained within the floating plastic covers (Lam & Lee, 2011). Such a biogas capture system has been applied in Malaysia in flaring and for utilisation as boiler fuel in power and heat generation and as feedstock for hydrogen production (Tong & Jaafar 2005, 2004; NOVAVIRO Technology Sdn Bhd, 2010). Moving forward, for optimal biogas generation to produce electricity, high-rate pressurized sliding anaerobic digester tank systems should be employed (see **Figure 4.4**) (Tong & Jaafar 2005).

Figure 4.4 A floating roof closed-tank anaerobic digester system for POME biogas capture in Malaysia

Source: NOVAVIRO Technology Sdn Bhd 2010

### 4.5.4 TECHNICAL CHALLENGES TO CULTIVATE MICROALGAE FROM POME FOR BIOENERGY PRODUCTION

Utilising POME as a nutrient source to culture microalgae is not a new practice in Malaysia. Most palm oil millers favour the culture of microalgae as a tertiary treatment measure before POME is discharged due to its high efficiency and low cost. Most nutrients such as nitrate and orthophosphate contained in POME, which are not removed during anaerobic digestion, are further treated in a microalgae pond. The cultured microalgae are used as a diet supplement for live feed culture (Lam and Lee, 2011). Nonetheless, a major challenge lies in the scale-up for commercialisation in terms of the prospective timeline for large-scale production. In particular, while conversion of microalgae to bioenergy is largely a problem that can be handled, microalgae cultivation remains a challenge.

### 4.6 BIODIESEL PRODUCTION FROM MICROALGAE

Microalgae biomass harvested from an open pond or a photobioreactor system can be subjected to a dehydration process to extract lipids that undergo a transesterification reaction to produce biodiesel as a main product and glycerol as a byproduct. There is a lot of interest in improving the economic potential and environmental prospect of microalgal biodiesel (Van Harmelen & Oonk 2006; Chisti 2007).

Current work has been focused on optimising large-scale cultivation, effective photobioreactor design, and increased lipids productivity. Extensive work is required on conversion technologies of microalgae lipid to biodiesel. For example, only homogeneous base catalysts are favoured for use hitherto to produce microalgal biodiesel mainly due to its easy preparation and fast reaction rate. Use of heterogeneous acid and enzymatic catalysts are still limited in the literature. There is also a knowledge gap on application of technologies such as ultrasonication, supercritical fluid, and microwave to enhance microalgae lipid conversion to biodiesel, which may improve the mass transfer rate (Lam & Lee 2011).

## 4.7 BIOETHANOL PRODUCTION FROM MICROALGAE

Microalgae are also a potential feedstock for bioethanol production. Apart from high lipid content suitable for producing biodiesel, microalgae also contain carbohydrates (generally not cellulose) and proteins that can be used as a carbon source or substrate for fermentation to produce bioethanol. Unlike terrestrial plants, green and blue-green microalgae are not lignocellulosic compounds, hence, pretreatment is not necessary which simplifies the bioethanol production scheme (Lam & Lee 2011).

## 4.8 TECHNICAL CHALLENGES FOR AN INTEGRATED BIOENERGY PRODUCTION SYSTEM

Lipid from microalgae can be extracted for biodiesel production prior to the hydrolysis and fermentation processes for bioethanol production. Subsequently, the remaining microalgae biomass post-fermentation can be utilised to produce biomethane through anaerobic digestion (Lam & Lee 2011).

The production of microalgal biofuels on a whole is not cost competitive currently as compared to conventional fuels. Thus, biofuels production from microalgae cultured from POME integrated with biomethane recovery offers potential to improve the associated economics and sustainability. The electricity generated by using biomethane recovery may surrogate the energy consumption required in microalgal cultivation, dewatering, extraction, and transesterification processes (Harun *et al.* 2011).

## 4.9 ENERGY PRODUCTION FROM MUNICIPAL SOLID WASTE LANDFILL GAS

Apart from POME, biogas can also be recovered from landfills in Malaysia in the decomposing of Municipal Solid Waste (MSW). The captured Landfill Gas (LFG), which is mainly biomethane, can be upgraded to pipeline-quality gas to produce electricity or directly as fuels for powering homes, factories, buildings, and vehicles. It is noteworthy that it is easier to design a new (sanitary) landfill for LFG utilisation rather than one that is retrofitted at a later stage.

### 4.9.1 PROSPECTS FOR BIOGAS FROM MUNICIPAL SOLID WASTE IN MALAYSIA

By definition, LFG utilisation involves gathering, processing, and treating the methane gas emitted from decomposing MSW (i.e., refuse or garbage) to generate power, heat, fuels, and various chemical compounds. Landfills are the highest methane generator in Malaysia at an estimated 53% of the country's total methane emissions in 2008. Comparatively, palm oil mill effluent (POME), swine manure, and industrial effluent each produces 38%, 6%, and 3%, respectively (Kamarudin 2008).

Landfill methane emissions are poised to grow in view of a burgeoning population and rapid urbanisation in Malaysia, coupled with a generally poor recycling program (Johari *et al.* 2012); all of which are factors that have directly increased MSW generation in Malaysia from 5.6 million tonnes (Mt) in 1997 to more than 8 Mt in 2010, with more than 9 Mt projected by 2020. Currently, there are only five operating sanitary landfills that recover methane out of the 104 in operation in Peninsular Malaysia (Noor *et al.* 2013). However, only the Bukit Tagar sanitary landfill in Hulu Selangor, Malaysia has successfully implemented LFG utilisation (see illustration in Figure 4.5).

Figure 4.5 Bukit Tagar Sanitary Landfill in Hulu Selangor, Malaysia

**Box 1: Sanitary landfills**

Sanitary landfills are sites where waste is isolated from the environment until it is safe in the sense that the waste has completely degraded biologically, chemically, and physically. The method entails an engineered practice of disposing of solid waste on land in a manner that protects the environment, by spreading the waste in thin layers, compacting it to the smallest practical volume, and covering it with compacted soil by the end of each working day or at more frequent intervals if necessary (MIT 2000).

Under the SREP programme, only five LFG projects, witg a total of 10.2 MW of electricity generation capacity, have been applied (Ludin *et al.* 2004). Thus, there is prospect for a systematic R&D-supported uptake and intensification of such initiatives to contribute towards meeting the national 2080 MW renewable energy target by 2020 (Government of Malaysia 2011).

Around the world, there are growing interests in LFG utilisation. For instance, success stories have been reported by participants of the Landfill Methane Outreach Program (LMOP) of U.S. Environmental Protection Agency (U.S. Environmental Protection Agency (EPA)). The number of LFG projects, which mainly convert the gas into power, increased from 399 in 2005 to 519 in 2009 (Koch 2010).

## 4.9.2 ADVANTAGES AND BENEFITS

The benefits of biomethane as elucidated for its capture from POME apply equally to the case of LFG recovery with regards to waste management, pollution reduction, GHG emissions abatement, and control of associated energy costs. Energy from LFG capture also contributes toward achieving the national renewable energy cumulative installed capacity target by 2020 (Government of Malaysia 2011).

In addition, LFG recovery presents pollution and hazard prevention opportunities. Because uncontrolled surface emissions of landfill gas into the air is a major health and environmental concerns, thus LFG energy projects provides assurance of cleaner air with reduced smog and odour. Furthermore, LFG utilisation contributes to better management of a landfill by reducing subsurface migration to other areas within its property or the surroundings while minimising the attendant fire and explosion hazards. As well, relative to conventional power plants relying on cooling water systems, LFG-based plants are typically smaller and generate smaller volumes of associated discharge into receiving water bodies (Noor *et al.* 2013).

In short, besides providing a renewable energy resource, LFG utilisation contributes towards environmental protection and prolonged landfill site life as well as economic and societal benefits in general.

## 4.9.3 TECHNICAL CHALLENGES TO GENERATE ENERGY FROM MUNICIPAL SOLID WASTE LANDFILL GAS

### 4.9.3.1 LANDFILL GAS COLLECTION SYSTEMS

The main reaction in a landfill designed for LFG capture is anaerobic biodegradation of the organic component of MSW, which thus emits gas (LFG). In most cases, the LFG is gathered through vertical extraction wells erected at a landfill with typically one well per acre (1 acre is equal to 4047 $m^2$). Alternatively, horizontal trenches can also be utilised for extracting LFG. The extracted LFGis piped to a main collection header and then sent for treatment or it is otherwise flared. Both vertical and horizontal orientations are effective collection systems (U.S. Environmental Protection Agency (EPA) 2009).

### 4.9.3.2 WASTE-TO-ENERGY TECHNOLOGIES FOR MUNICIPAL SOLID WASTE LANDFILL GAS

Most waste-to-energy technologies require pretreated MSW as input feed, and they are thermochemical technologies, such as conventional incineration, gasification, pyrolysis, and plasma technologies—the latter include gasification, vitrification and their combinations. MSW is a heterogeneous feedstock containing materials with widely varying sizes, shapes, and composition. As a result, the use of MSW as received (i.e. without pretreatment) can lead to variable and even unstable operating conditions, attending to end productswith fluctuating quality. Moreover, the more advanced thermochemical treatment technologies require sufficiently high calorific value input to obtain high efficiencies.

For these reasons, Refuse Derived Fuel (RDF),a processed form of MSWis often used as an input. The general process for converting MSW into RDF involves shredding, screening, sorting, drying, and/or pelletisation to improve handling characteristics and material homogeneity. Importantly, to obtain a high quality RDF, the pretreatmentprocess should be carefully matched to waste properties from an excavated landfill site. It is equally vital that the characteristics and composition of MSW excavated from a landfill is within the feed requirement range of a certain technology. However, the conversion of MSW into RDF requires high capital and operating expenditures—the latter is due to a high energy input requirement.

The resulting benefits of converting MSW to RDF are a higher calorific value, more homogeneous physical and chemical compositions, lower pollutant emissions, lower ash content, reduced excess air requirement during combustion, and consequently easier storage, handling and transportation. Hence, a trade-off between the increased costs of converting MSW to RDF and the potential cost reduction in the system design and operation is a crucial issue to be studied (Bosmans *et al.* 2013; Syed Abd Kadir *et al.* 2013). In the context of its implementation in Malaysia, an only existing installation is the resource recovery centre-cum-waste-to-energy (RRC/WtE) plant in Semenyih, Selangor, Malaysia that is operated by Recycle Energy Sdn. Bhd. with an MSW processing capacity of 1000 ton/day (see illustration in. The lack of success story in terms of actual operating sites (as compared to those employing direct combustion technology) have casted doubts on the viability of the technology.

Figure 4.6 Waste-to-Energy plant at Semenyih Resource Recovery Centre in Semenyih, Selangor, Malaysia

## 4.10 ENERGY PRODUCTION FROM SMALL HYDROPOWER

### 4.10.1 PROSPECTS

Small scale hydropower stations offer low operating cost, reliability due to the mature technology employed, and. A small hydroelectric facility is particularly suitable for implementation in locations far away from the main electricity grid that face difficulty to receive power supply.

According to official statistics, there are 26 approved small hydropower projects under the SREP program at total generation capacity of 101.9 MW with grid-connected capacity of 97.4 MW. An estimated 490–500 MW of small hydropower is potentially available in Malaysia by 2020, but only 29 MW is utilised in power stations in year 2008. The installed capacity of small hydropower stations are mainly found in Sabah and Sarawak, with a total capacity of 8.3 MW and 7.3 MW, respectively (Ong *et al.* 2011; KeTTHA 2007).

## 4.10.2 ADVANTAGES AND BENEFITS

The advantages of small hydropower stations are numerous as it is renewable, clean, reliable, pollution-free, and cheap in terms of low levelised cost of electricity. Moreover, the power generated is less affected by fluctuation in fossil fuel prices and thus is a viable substitute to back out increasing coal imports in Malaysia's power generation mix (Chin *et al.* 2013). Small hydropower studies conducted in Malaysia have found the technology to be viable economically particularly when considered with the additional benefits offered by flood and irrigation control and in promoting eco-tourism.

Hydroelectric is also a viable alternative power source for remote villages (e.g., in Sabah and Sarawak) that otherwise would have to depend on diesel-powered generators. Such a project implementation can be self-financing, while it also obviates a need for diesel fuel use (requiring it only on standby). It is reported that TNB has completed rehabilitation of 26 small hydropower plants with a total capacity of 12.3 MW by middle of 2011 with possible capacity expansion (Ong *et al.* 2011).

## 4.10.3 TECHNICAL CHALLENGES

Developing a small hydroelectric power plant largely involves a proven mature technology (IRENA 2012). Suitable small hydropower installations are one based on run-of-river schemes with maximum generating capacity of 10–30 MW as stipulated under the FiT scheme in Malaysia. Alternatively, a dam-toe project from a water supply scheme may be considered (Haris & Ding 2009).

A common obstacle in small hydropower development is the remote location. According to FiT, for a project to be feasible, it should be located within about 10 km or less from points of interconnection (KeTTHA 2008). Nonetheless, a challenge in the concerns of land use management (and the associated hydraulic flow) by the respective State government agencies in view of the mudslide flood in Bertam Valley, Cameron Highlands in November 2013. **Figure 4.7** shows a TNB mini hydropower dam at 1.65 km from Sungai Mentawak, Pahang near the Bertam Valley.

Figure 4.7 Tenaga Nasional Berhad (TNB) mini hydropower dam at1.65m from Sungai Mentawak, Pahang near the Bertam Valley

## 4.11 DEVELOPMENT OF LARGE SCALE NATIONAL SOLAR PHOTOVOLTAIC INDUSTRY

### 4.11.1 PROSPECTS

In the previous study Mega Science Framework on Sustained National Development for 2011–2057 for the Energy Sector (or referred to as the 'Mega Science 1.0' study), it has been proposed that since Malaysia has established grounds in the solar PV manufacturing industry mainly through the Malaysia Building Integrated Photovoltaic (MBIPV) (2005–2011) project (Haris & Ding 2009), there exist opportunities for expansion to become a major industry penetrating international markets. We revisit the proposed measures as part of our recommendations in the present Mega Science 2.0 study.

### 4.11.2 ADVANTAGES AND BENEFITS

The following advantages and benefits are anticipated from the creation of a large scale national solar PV industry:

- establish a new technology sector with high growth potential and creation of thousands of jobs;
- turn Malaysia into a world leading solar PV equipment manufacturer with indigenous technology;
- generation of multibillion revenue with direct returns for reinvestment for the industry and contribution to national GDP; and
- provision of direct benefits to local industries which form part of the value chain.

### 4.11.3 TECHNICAL AND COMMERCIAL CHALLENGES

In addition to current existing measures under RE Act 2011 and the FiT implementation, the following are recommendations to support the government in building a national solar PV industry.

**(a) To nurture a conducive market environment (on top of initiatives legislated under the RE Act 2011 and FiT):**

- promoting public awareness and implementing advocacy programmes;
- installing solar PV systems in government buildings and promoting Green Building Index (GBI) compliance; and
- designing a long-term national energy policy based on renewable energy particularly solar PV.

**(b) To enhance industry participation by**:

- creating coordination between various government agencies in developing a local solar PV industry;
- intensifying human capital development, (e.g. by focusing on industry missions, sponsored exchange programs such as apprenticeships, and training abroad);
- facilitating partnerships between multinational companies and local industries;
- upgrading targeted local industries to solar PV business-related activities (e.g., wafer fabrication in the electronics industry) to leverage on lower costs, lower entry levels, and faster implementation; and
- introducing industry demonstration and quality programmes and award schemes.

**(c) To build infrastructure by**:

- introducing business facilitation packages, e.g., soft loan schemes and focus grants for local industries to enter and expand the solar PV business;
- promoting intellectual property acquisition and foreign direct investments with focus on direct benefits for local industries, thus triggering domestic direct investments; and
- identifying Government or GLC investments in new promising solar PV technologies and catalysethe development, incubation, as well as creation of fast spin-off companies;

**(d) To promote research, development and innovation by**:

- designing and implementing a national solar PV R&D roadmap with focus on technology innovation and cost reduction;
- establishing internationally-certified test facilities and a solar PV R&D centre to support required R&D activities;
- increasing R&D budget for solar PV technology and process development with constant monitoring and feedback from the industry;
- establishing a review and advisory committee of local and international experts;
- enhancing collaboration between industry and academia;
- exploiting the Brain Gain Malaysia program with a special focus on solar PV technology; and
- fostering growth of technopreneurs.

A particular technical challenge to build a sustainable national solar PV industry is to address the hazardous waste generated in its production through proper treatment of its effluent, such as, hydrofluoric acid. Another avenue is to conduct R&D on clean technology for manufacturing solar cells and panels that require less water and involves less toxic materials, e.g.silane gas and hydrochloric acid in crystalline silicon solar PV production, which is the most common technology (Drouiche*et al.* 2013). In this regard, appropriate funding support from AkaunAmanahIndustriBekalanElektrik (AAIBE or MESITA) will be crucial.

## 4.12 ENERGY STORAGE TECHNOLOGIES

### 4.12.1 PROSPECTS

Energy storage technology is an important consideration to address the inherent instability and intermittent nature of electricity generation from the foregoing renewable energy options proposed, for instance, due to the dependence of solar PV on solar irradiation. In particular, the integration of energy storage into a national electricity grid is necessary to store surplus of energy generated from renewables and to enable energy to be drawn from storage to handle periods of power production shortfall from renewables (U.S. Department of Energy 2013).

A report by the investment bank Morgan Stanley in March 2014 predicts a substantial reduction in energy storage cost and indicates the potential impact of battery storage (Parkinson 2014). An article by The Economist on the aforementioned report postulates the extent of such impact to the possibility of even eroding the monopoly of electric utility as customers reduce their dependence on the grid to lower energy costs by adopting solar PV and battery storage technologies (The Economist 2014).

### 4.12.2 ADVANTAGES AND BENEFITS

Developing and deploying energy storage allows more renewable power capacity to be made accessible to the grid, which is an important strategy inaddressing climate change. On the supply side, energy storage reduces operating cost and increases efficiency of generation by storing electricity during low demand or high production level while providing electricity at times of peak demand or low production level.

On the demand side, energy storage enables low cost power to be used during periods of peak electricity demand while allowing renewable energy to be available as needed, thus reducing consumer costs (U.S. Department of Energy 2013). Consequently, the grid's operating capabilities and reliability are improved besides reducing transmission costs as well as the risk and damage of power cuts. Energy storage also provides backup power, grid stabilisation, and frequency regulation that are pertinent for emergency preparedness besides other multiple applications for energy management, load levelling, and voltage support (Poullikkas 2013).

### 4.12.3 TECHNICAL CHALLENGES

Main types of energy storage technologies are Pumped Hydroelectric Energy Storage (PHES); Compressed Air Energy Storage (CAES); various types of batteries (chemical (e.g., lead–acid, Nickel Cadmium (Ni–Cd), Nickel–Metal Hydride (NiMH), Lithium Ion (Li-ion), sodium–sulphur (NaS), and Sodium nickel–chloride (Na–Ni–Cl or zebra)), redox flow, and metal–air); flywheels; electrochemical supercapacitors; Superconducting Magnetic Energy Storage (SMES); hydrogen storage systems (using fuel cells); and Thermal Energy Storage (TES). Reviews on electrical energy storage technologies are available in Chen et al. (2009) and more recently by Ferreira et al. (2013).

The goals of an R&D programme in energy storage will be two-pronged: (1) to enable energy storage to be deployed to support a high level of renewable energy generation, and (2) to make energy storage available as a plausible option to address grid reliability and resiliency issues. According to the U.S. Department of Energy (2013), four challenges that must be addressed if energy storage is to be widely developed and accepted are: (1) to develop cost-effective energy storage technologies including for manufacturing and grid integration, (2) to validate the reliability and safety of energy storage technologies, (3) to establish an equitable regulatory environment, and (4) to gain industry acceptance.

**Table 4.4** provides a list of mature and potential energy storage technologies for various applications (Ferreira *et al.*2013). As far as research undertaken locally in Malaysia is concerned, the area has not received much attention in experimental- nor modeling-based investigations with only a handful of published work to date (e.g.*Rismanchi et al.* 2012, 2013; Ho *et al.* 2013), just to cite a few.

Table 4.4 Mature and Potential Energy Storage Technologies for Various Applications

| Category | Application | Mature Technology | Potential Technology |
|---|---|---|---|
| Bulk energy storage | Load levelling, spinning reserve, peak shaving and valley filling, contingency service, area control | PHES, CAES, TES, Ni–Cd, lead–acid | Flow batteries, hydrogen storagesystems (using fuel cells) |
| | | | |
| Distributed storage | Peak shaving and valley filling, investment deferral, load following, demand side management, loss reduction, contingency service, black start, area control | CAES, flywheels, lead–acid, NaS, Ni–Cd, TES | Fuel cells, metal–air |
| | | | |
| Power quality | Power quality, intermittency mitigation, end-use applications, black start | Supercapacitors, lead–acid, NaS, flywheels | Li-ion, NiMH, SMES, zebra |

## 4.13 NUCLEAR ENERGY GENERATION USING THORIUM-BASED TECHNOLOGY

### 4.13.1 PROSPECTS

Addressing the real and perceived dangers of nuclear energy is of utmost importance for deploying power generation from this source in Malaysia, especially in light of the Fukushima Daiichi accident in 2011. In this regard, the use of thorium as the main fuel cycle for nuclear power shows potential, particularly liquid fluoride thorium reactors, compared to uranium which is the basic material in today's operating commercial technology.

### 4.13.2 ADVANTAGES AND BENEFITS OF THORIUM- BASED NUCLEAR POWER TECHNOLOGY

Thorium-based nuclear power technology has advantages in terms of source availability, safety, environmental impact, and economic efficiency relative to today's commercial uranium-based and solid oxide nuclear power. Primarily, as a basic material source of nuclear fuel, thorium is considerably more abundant than uranium besides producing less long-lived radioactive waste and is less conducive to proliferation dangers of weapon-grade materials—the latter of which may be crucial to gain international approval for its development in Malaysia (Schaffer 2013; Cooper *et al.* 2011). These advantages and other benefits are elaborated in the rest of this section.

### 4.13.3 AVAILABILITY OF THORIUM

Thorium ore is well distributed across the world and is estimated to be three-to-four times more abundant in nature than uranium. According to statistics reported by the United States Geological Survey (2010), Malaysia is reported to have 4,500 tonne of thorium resources. It is estimated that this amount is sufficient to provide adequate grid-connected electrical power for Malaysia over a long duration, although, subject to actual commercialisation(Schaffer 2013; Cooper *et al.* 2011)

### 4.13.4 EXTRACTION OF THORIUM

Thorium occurs naturally in only one isotope ($^{232}Th$) and is almost always found in rare earth metals mining (Cooper *et al.* 2011). Its primary source is monazite that contains 6–12% thorium phosphate. Extraction of thorium from monazite involves a complex multi-stage process but incurs relatively inexpensive chemical separation from its ore impurities (Schaffer 2013).

### 4.13.5 LOW WASTE PRODUCTION, STORAGE AND DISPOSAL

Use of thorium has important nuclear waste disposal advantages. Compared to uranium reactors, thorium reactors produce substantially less long-lived radioactive waste and as such, can be configured to minimise waste storage and disposal issues (Schaffer 2013).

### 4.13.6 PROLIFERATION RESISTANCE

There are important advantages related to nuclear weapon non-proliferation as regards thorium as a nuclear fuel. Use of thorium presents significant potential for minimisingalthough not eliminating the inherent dangers from the presence of materials needed for nuclear weapon development. This is mainly because uranium-233, which is used in producing a military bomb, is typically contaminated with the highly-radioactive uranium-232 in a thorium fuel cycle, and therefore is not easily separated from it. Thus, the use of thorium offers a substantial although not foolproof degree of proliferation resistance, which may augur well towards international community acceptance for its development in Malaysia (Schaffer 2013).

Apart from that, the use of thorium also reduces proliferation risks. This is because it eliminates a need for all enrichment activities inherent in uranium mining and processing. Namely, a perpetual need for transporting enriched uranium in itself presents a risk for proliferation.

### 4.13.7 HIGHER POWER GENERATION EFFICIENCY

It is estimated that a well-designed thorium reactor can produce electricity less expensively than a next-generation coal-fired power plant or a current-generation uranium-fuelled nuclear reactor (Schaffer 2013).

### 4.13.8 TECHNICAL CHALLENGES FOR LIQUID FLUORIDE THORIUM REACTORS

Thorium is well suited to a variety of reactor types including molten fluoride salt designs, heavy water CANDU (CANada Deuterium Uranium) configurations, and helium-cooled TRISO (triple-coated isotropic)-fueled systems (Schaffer 2013). In particular, Liquid Fluoride Thorium Reactors (LFTR, which is of the first type) can achieve high operating temperatures at atmospheric pressure, thus enabling higher thermal efficiency Brayton cycle-based nitrogen generators (about 50%) to be employed rather than steam generators (about 35%) (Cooper *et al.* 2011).

Apart from displaying all the advantage and benefits as discussed in the previous section, LFTR most importantly presents a potential for significant safety improvement in adverting the possibility of a catastrophic explosive accident such as Fukushima Daiichi or Chernobyl (Mathieu 2006). This advantage is mainly related to its inherent safety features with use of passive components and a strong negative temperature coefficient of reactivity, which has the effect when temperature in the reactor increases, the rate of nuclear fission decreases (Schaffer 2013).

In additional, in terms of environmental issues, LFTR poses a relatively smaller radiation risk because its fissile products are chemically bonded to the fluoride salt, thus the resulting radiation is captured and consequently averts radioactive material spread to the environment (Cooper *et al.*2011).The LFTR technology was first investigated at the US Oak Ridge National Laboratory through the molten salt reactor experiment in the 1960s. It has recently been the subject of a renewed interest worldwide in which the governments of India, Japan, China, the UK, Belgium as well as private US, Swiss, Czech, and Australian companies have expressed intent to develop and commercialise the technology (Schaffer 2013).

Although the unique characteristics of LFTR gives rise to potential advantages, there are challenges simply because the technology deviates significantly from today's operating commercial power reactors. There are only a few experimental LFTR units known to be built and they have been constructed around its birth in the 1960s, as alluded to. Thus, it has been claimed that it is difficult to assess the technology critically relative to today's State-of-the-art, mainly because it entails different design challenges apart from trade-offs with varying levels of political difficulties for its commercial potential deployment (Forsberg 2006; Forsberg *et al.* 2011).

## 4.14 ENERGY EFFICIENCY AND CONSERVATION

### 4.14.1 PROSPECTS

Energy efficiency and conservation has been touted as the best new energy resource. Malaysia possesses largely untapped potential for energy saving through energy efficiency measures in part because of the marginal incentive offered by low electricity prices resulting from high government fuel subsidies. The Economic Transformation Programme (ETP) of Malaysia foresees that the nation's energy use will be cut by 10–15% by 2020 by adopting various energy efficiency initiatives as compared to business-as-usual practices (PEMANDU 2010). On top of that, a 10% reduction in Malaysia's electricity consumption is targeted in 2020 under the National Energy Efficiency Master Plan (NEEMP) (Asia-Pacific Economic Cooperation 2011).

### 4.14.2 ADVANTAGES AND BENEFITS

By virtue of the relatively little investment required for their implementation, energy efficiency measures are often seen as low-hanging fruits in return for the significant benefits offered. Furthermore, the initiatives encourage local participation and ensure community resilience as they are largely carried out locally. It goes without saying that energy efficiency actions entail less use of energy and by extension, reduces air pollution and GHG emissions.

### 4.14.3 TECHNICAL CHALLENGES

The following energy efficiency and conservation measures have been identified in an advisory report published by the Academy of Sciences Malaysia titled "Sustainable Energy Options for Electric Power Generation in Peninsular Malaysia to 2030" (Chin *et al.* 2013):

- implement cogeneration and tri-generation of power and heating and cooling duties to address significant efficiency losses in transmission and distribution of electric power;
- replace incandescent lamps with compact fluorescent and LED lamps (KeTTHA has mandated the phasing out of incandescent lamps by 2014);
- replace tubular T-8 fluorescent lamps, which are commonly used for commercial and residential use, with the more efficient T-5 tubes (or their LED alternatives) that give the same lighting level but at about two-thirds of the energy consumed;
- use 5-star energy efficient refrigerators (KeTTHA has promoted them under its Sustainability Achieved Via Energy Efficiency (SAVE) programme since 2011;
- replace window or split type air-conditioners with the 5-star or inverter type equivalent models;
- install and enhance insulation for roof, wall, and window to help reduce cooling power demand; and
- replace the existing older chillers in commercial and certain industrial users to benefit from the technology improvement of new efficient large centralised chillers.

## 4.15 SCIENCE, TECHNOLOGY AND INNOVATION OPPORTUNITIES

This section consolidates the STI opportunities for environmentally-sustainable energy production for Malaysia in the short term (2014–2020), medium term (2021–2035), and long term (2035–2050).

For the STI opportunity of energy production from lignocellulosic biomass-based second-generation bioethanol, in the short term, a focus will be to perform a raw material assessment of biomass, notably Empty Fruit Bunch (EFB). In particular, there will be a need to improve the economics of EFB utilisation for local energy generation needs in which currently, EFB in pellet form as a fuel source is exported overseas at a price that offers little incentive for its use as a coal substitute for local electricity generation (Agensi Inovasi Malaysia 2011; Umar *et al.* 2013).

Another area is to conduct R&D on technologies for pretreatment to solubilise the hemicellulose and for fermentation. Commercialisation efforts of these technologies will be the emphasis in the medium term. It is also important to establish the infrastructure to support a bioethanol supply chain from raw material sources to the market or demand centres. The aim in the long term will be to promote and develop an economically-viable industry for the production and blending of bioethanol with gasoline (petrol) for transportation fuel at a scale sufficient to meet the nation's demand.

For the STI opportunity of energy production from integrated POME biogas recovery and microalgae cultivation, a short term emphasis will be a three-pronged industry-wide measure on biogas plants to: (1) encourage use of high-rate anaerobic digesting tanks in thermophilic (and not mesophilic) condition for optimal biomethane capture for electricity generation; (2) equip operation with supervisory control and data acquisition (SCADA) control system; and (3) allow palm oil mills with such facility that are not connected to the national electricity grid to receive FiT.

In the medium term, attention will be concentrated on commercialising microalgae cultivation for bioethanol and biodiesel production to sufficient scale to meet market demand. On the other hand, efforts are required in building human capacity for maintenance of biogas plants to produce electricity up to a potential of 1000 MW. Development of an integrated system of biogas recovery for electricity generation and microalgae cultivation for biofuels production with attractive rate of return on investments will be a focus for the long-term STI efforts.

In spearheading the STI opportunity on energy production from municipal solid waste LFG utilisation, technology R&D development will be the area of concentration in the short term with regards to identifying suitable technologies for LFG collection as well as to centralize existing landfills into regional sites. Subsequently, a medium term emphasis will be to enforce grassroots design of all new sanitary landfills to be anaerobic systems to enable LFG collection and utilisation for electricity production. The long term efforts will be geared towards employing an integrated solid waste management approach to replace current landfills, incineration, and RDF systems with resulting potential electricity production at an estimated 300 MW.

Hence, enforcing a need for feasibility studies of small hydropower projects particularly in terms of the surrounding land use management will be an STI opportunity in the short term in an effort to increase its installed electricity generation capacity up to a potential of 500 MW as originally projected by KeTTHA (2008). In the long run, there will be opportunity to consider large-scale installations of micro hydropower (less than 100 kW capacity) and pico hydropower (less than 10 kW capacity) stations for remote communities. In tandem with this, renewable energy supply from a sustainable large-scale national solar PV industry as envisioned in the preceding Mega Science 1.0 study can be achieved by conducting intensive R&D activities to commercialise the technologies for waste treatmentand clean manufacturing technology for solar PV cells and panels.

The short-term STI opportunities to develop cost-competitive energy storage technologies can only be achieved through research; resolving economic and performance barriers, and creating analytical tools for design, manufacturing, innovation and deployment. In the medium-term, the reliability and safety of energy storage technologies can be validated through research and development, creation of standard testing protocols, independent testing against utility requirements, and documenting the performance of installed systems.

In addition, a need arises to establish an equitable regulatory environment by conducting public-private evaluations of grid benefits, exploring technology-neutral mechanisms for monetising grid services, and developing industry and regulatory agency-accepted standards for sitting, grid integration, procurement, and performance evaluation. The long term focus will be to gain industry acceptance can be accomplished through field trials and demonstrations to ensure scalability and to reduce operational uncertainty through use of industry-accepted planning and operational tools to incorporate storage onto the grid (U.S. Department of Energy 2013).

An immediate STI need for generating electricity in Malaysia from nuclear sources will be to conduct R&D on the feasibility of deploying liquid fluoride thorium reactors (LFTR) including to engage the wider public in consultation processes and awareness campaigns. The medium-term focus to 2035 will be on building highly skilled manpower with the requisite operation and maintenance capability to achieve a 20% share of national electricity generation mix. This share is as opposed to the 50.3% target projected by Suruhanjaya Tenaga (2012), which will be deemed as a more feasible long term STI opportunity provided that the perennial issue of managing radioactive waste is addressed.

Last but not least, energy efficiency and conservation measures hold enormous potential for environmentally conscious energy saving for the nation. Current ongoing initiatives as helmed by KeTTHA will continue to drive the short-term efforts whereas the medium-term emphasis will involve improving air-conditioning and lighting energy use in commercial and industrial users through widespread replacement of old large centralised chillers and adoption of energy efficient lighting. In the long term, it is envisaged that policy-driven leadership will be crucial to moderate energy subsidies in view of gradual complete removal. **Table 4.5** summarises the STI opportunities outlined for the three time scales for environmentally-sustainable energy production for Malaysia.

## 4.18 CONCLUSION

This chapter serves to identify, deliberate, and reflect upon STI opportunities that are potentially viable to meet the energy demands of Malaysia in an environmentally sustainable manner. In view of the large biomass resources of the nation, potential renewable energy generation options from biomass wastes are advocated, namely (1) second-generation bioethanol mainly from EFB (2) electricity generation and biofuels production from integrated POME biogas recovery and microalgae cultivation, respectively, and (3) electricity generation in landfill gas utilisation from MSW. Nonetheless, a common challenge to address across the three biomass-based energy generation opportunities is to attain substantial production scale with economic viability within a feasible timeline, and to develop energy storage infrastructure to enhance the renewables capacity. The chapter also critically reviews other energy resources that are relevant to safeguarding the environment, which include small hydropower, solar PV, nuclear power, and energy efficiency.

Table 4.5 Summary of STI Opportunities for Environmentally-Sustainable Energy Production for Malaysia

| Energy Production Source | STI Opportunity | | |
|---|---|---|---|
| | Short Term (2014–2020) | Medium Term (2021–2035) | Long Term (2036–2050) |
| Second-generation bioethanol | • Assess feedstock availability of biomass particularly EFB<br>• Improve economics of EFB utilisation for energy generation<br>• Conduct technology R&D on pretreatment and fermentation of biomass | • Commercialise technology for pretreatment and fermentation<br>• Develop supply chain from raw material to market | Develop economically-viable industrial-scale production of bioethanol-blended petrol to meet transportation fuel demand |
| Integrated POME biogas recovery and microalgae cultivation | • Encourage use of high-rate thermophilic anaerobic digesting tanks<br>• Equip biogas plants with SCADA control system<br>• Allow palm oil mills with biogas recovery that are not connected to the grid to receive FiT | • Build human capacity in maintenance of biogas plants to produce up to 1000 MW of electricity<br>• Commercialise microalgae cultivation technology for biofuels production to sufficient scale | Develop integrated system of biogas recovery and microalgae cultivation |
| Municipal solid waste landfill gas | • Identify suitable technologies for LFG collection<br>• Centralize existing landfills into regional sites | Enforce grassroots design of all new sanitary landfills to be anaerobic systems to enable LFG collection and utilisation for electricity generation | Employ an integrated solid waste management approach with potential electricity generation of 300 MW |
| Small hydropower | Enforce need for project feasibility study particularly in terms of surrounding land use management | Increase installed generation capacity to 500 MW | Install micro hydro (<100 kW) and pico hydro (<10 kW) for remote communities at a large scale |
| Large scale national solar PV industry | • Nurture a conducive market environment<br>• Enhance industry participation<br>• Build infrastructure<br>• Promote R&D activities | Conduct R&D on waste treatmentand clean manufacturing technology for solar PV cells and panels | Commercialise technology for waste treatmentand clean manufacturing technology for solar PV cells and panels |

| Energy Production Source | STI Opportunity | | |
|---|---|---|---|
| | **Short Term (2014–2020)** | **Medium Term (2021–2035)** | **Long Term (2036–2050)** |
| Energy storage | Develop high capacity and cost-effective technologies | • Validate reliability and safety of technologies<br>• Establish an equitable regulatory environment | Gain industry acceptance |
| Thorium-based nuclear power | Conduct R&D on feasibility of deploying LFTR in Malaysia | Build manpower capability to achieve 20% share of national electricity generation mix | Attain a 50% share of national electricity generation mix |
| Energy efficiency | Implement cogeneration and trigeneration of power and heating and cooling duties<br>• Use compact fluorescent and LED lamps and tubular T-5 fluorescent lamps<br>• Use 5-star energy efficient refrigerators<br>• Use 5-star or inverter type air-conditioners<br>• Enhance insulation for roof, wall, and window | Improve air-conditioning and lighting energy use in commercial and industrial users by replacing old large centralised chillers and adopting energy efficient lighting | Adopt policy-driven leadership to moderate energy subsidies in view of gradual removal |

# CHAPTER 5

## WASTE MANAGEMENT

The increase in population results in increase in the volume and types of generated waste. It is known that cities cover 2% of the world's surface, but generate 70% of the world's waste. Hence, with increasing urban populations and consumption in developing nations, the level of urban waste can be expected to continue growing. In this chapter are described ways and means to minimise waste in keeping with environmental standards and sustainability. The data presented will be useful in preparing guidelines for development, review and updating of national waste management strategies and moving from challenges to opportunities (UNEP 2012-2013).

The basic concepts, targets, policy instruments, methods and models are available in various journals (Juul, *et al.* 2013) and in published documents of national and international agencies e.g. the European Commission's Directive 2008/98/EC on waste (DCCW, Waste Framework Directive, 2009);Roadmap to a Resource-Efficient Europe (Council of the European Union 24 May 2013, 9701/13); Annex to the World Bank's World Development Report, Chapter 9 - The Costs of A Better Environment.

As a whole, Europe reuses or recycles 40% of solid waste and the rest goes to landfills and incineration. Some streams of wastes such as construction and demolition waste, sewage sludge and marine litter are increasing. Electrical and electronic waste is expected to increase roughly to 11% by 2015. Some countries such as Germany and Denmark, have very high reuse rates of 70-80%. These countries ban organic wastes (such as food) from being disposed in landfills and have increased their landfill tax by 50% which means 30 EURO or more per tonne of waste.

Other successful measures include mandatory separate collection of different types of waste, such as paper or bio-waste and this reduces the transport costs for collection of waste by 11% (Ramos, *et al.* 2013). Separate collection of paper, metal, plastic and glass which will be implemented to 2015 additionally will increase recycling rate. In the (DCCW 2009) Waste Framework Directive it is written that 50% from all household waste should be prepared for reuse or recycling by 2020. By the year 2020, EU waste generation will decline drastically, waste legislation will be fully implemented, illegal shipment of waste will be eradicated, and landfilling will be strongly eliminated. These are some of the targets that Malaysia could also aim for.

## 5.1 MUNICIPAL, INDUSTRIAL AND CITY WASTE MANAGEMENT

Municipal Solid Waste (MSW), more commonly known as trash or garbage, consists of everyday items we use and then throw away, this includes such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses.

In 2011, Americans generated about 250 million tons of trash and recycled and composted almost 87 million tons of this material, equivalent to a 34.7% recycling rate. On average, they recycled and composted 1.53 pounds of the individual waste generation of 4.40 pounds per person per day. According to the American Environmental Protection Agency (2006) the distribution of municipal solid wastes was as follows: food waste: 14.5%; paper & paper board: 28.0%; glass: 4.6%; metals: 8.8%; plastic: 12.7%; rubber, leather & textiles: 8.2%; wood: 6.4%; yard trimmings: 13.5%.

Currently daily generation of MSW in Malaysia has exceeded 28,000 tonnes (**Figure 5.1**) and with the existing trend, it is expected to reach more than 38,000 tonnes by 2020. The trend line type is linear and showed proportional increase of generated solid waste with years. (Agamuthu 2010; Agamuthu *et. al.* 2011).The main component in Malaysian MSW is organic waste which contributes approximately 40% of the total waste stream. The high organic content is a typical characteristic of waste disposed by developing countries in the world (Agamuthu 2010). This is followed by 15% of paper and 14% plastics.

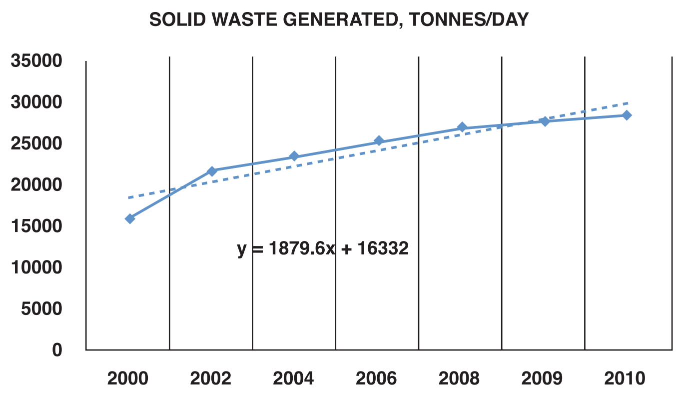



Figure 5.1 Total generation of MSW in Peninsula Malaysia

Source: Agamuthu 2010

### 5.1.1 THREE APPROACHES TO MUNICIPAL WASTE MANAGEMENT

Treating waste with CaO to pH=14, sterilises it, and thus, preventing further chemical and microbiological degradation. Then, the waste is covered with plastic and disposed in landfills. This approach is the cheapest, and companies which are responsible for disposal of the municipal waste prefer this approach.Next, is to convert all the municipal waste into energy by incineration, but control of atmosphere contamination requires expensive air filters. The third approach involves separation of waste into various components. Some components are recycled. The biodegradable component is used to produce compost which is applied to agricultural crops. The rest is incinerated to produce energy.

This approach is favoured in Europe and would be most suitable for Malaysia. The efficiency of reuse depends strongly on methods applied for separation of the waste. Despite EU-wide recycling targets and successes in certain areas, Europe's waste is still a hugely under-used resource. A study prepared for the EU Commission estimates that full implementation of EU waste legislation would save EUR 72 billion a year, increase the annual turnover of the EU waste management and recycling sector by EUR 42 billion, and create over 400,000 new jobs by 2020 (Europe Press Room 2014).

Several other methods and technologies are available for producing biofuel and electricity using thermal, plasma, pyrolysis, and hydrolysis treatments of MSW (Schneider & Ragossing 2013; Costas, *et al.* 2013). These technologies can replace so called food crop biofuels with waste fuel thus converting waste into resource. The modern MSW combustion plants (also known as Waste-to-Energy (WtE), are much improved as compared to those in the 1960's, 1970's and 1980's by introducing air emission reduction technologies.

A new tool to improve the measurement of waste management performance has been suggested by Zaman and Lehman (2013). The researchers applied it to three high consuming cities aspiring to "zero waste", finding San Francisco to be closer to achieving zero waste than Stockholm and Adelaide, due to its emphasis on reusing solid waste. The Zero Waste Index proposes quantifies solid waste flows and measures the extent to which materials may be reused as substitutes for virgin materials. The approach includes other savings made including energy saved, greenhouse gases avoided and water savings. They found that San Francisco scored 0.51, meaning that around half of its municipal waste materials were recovered and therefore had potential to replace the demand for virgin materials. For comparison Stockholm scored just 0.17 although it produces less waste per capita but with very high level of incineration which means large losses of raw materials. San Francisco also achieved greater energy and greenhouse gas savings, as well as greater water savings.

Recycling of metals is difficult because of the presence of rare metals as impurities (Reck & Graedel 2012). This is particular true for aluminium which is very intolerant to any impurities. Incentives are needed to promote metal collection and sorting and to encourage product designers to take recycling more seriously. Products can be designed for easier disassembly of metal-rich components. In Europe legislated incentives favour steel and base metals, such as iron, copper and zinc which are relatively easier to recover compared to some of the specialty metals contained in electronics. Nevertheless, between 25% and 40% of waste from electrical and electronic equipment is recycled. Overall, researchers regard collection as key mechanism for improving metal recycling.

### 5.1.2 CONSTRUCTION AND DEMOLITION WASTE

Coelho and de Brito (2013) found that environmental benefits of recycling construction and demolition waste are considerable even after accounting for the impacts of the recycling process itself. Recycling cam plays a vital role in reducing the negative environmental impact of the construction industry. Recycling plants receive mixed materials and separate them into waste types such as concrete aggregates, metals, paper and plastics.

It is interesting to note the experience of construction waste management in Hong Kong (Weisheng Lu &Hongping Yuan 2012). The new construction waste policy management significantly minimises construction waste by offsite construction waste sorting. Also they use policy instruments such as charging 11.98 EURO for every ton disposed of at landfill and 9.59 EURO per ton if construction waste is accepted by off-site sorting facilities. The European Waste Framework Directive (DECCW 2009) includes the target of reusing, recycling or otherwise recovering of 70% of construction and demolition waste by 2020.

## 5.2 COMPOSTING THE BIODEGRADABLE PART OF MSW

The biodegradable part of municipal waste which represent 70% of MSW in developing countries is coming from household residues (**Figure 5.3**). Composting of biodegradable part of MSW is common practice of

EU members after introduction of two laws, one for conservation of organic matter of soils and the other to promote composting of the biodegradable part in MSW. During composting of biodegradable part of MSW, temperatures rise and thermophilic conditions (above 55°C) kills pathogens and seeds of weeds. In a number of publications there are descriptions of composting process, microbes participating in composting and good quality of final product from composting (Strom 1985; Nakasaki, K *et al.* 1987; Thambirajah *et al.* 2006; Elango *et al.* 2009).

## 5.3 PLASTIC, GLASS, IRON, ALUMINIUM AND PAPER WASTE

Plastic has become the most common material since the beginning of the 20th century and modern life is unthinkable without it. Unfortunately, what makes it so useful, such as its durability, light weight and low cost, also makes it problematic when it comes to its end of life phase and become waste (EU waste: Plastic waste: updated February 2014; EU waste: Plastic garbage: updated February 2014). The massive pollution of the oceans with plastic debris is emerging as a global challenge that requires a global response. Plastic cannot be considered as inert material. Microplastic fragments of less than 5mm, are of increasing concern. Microplastic debris can enter into the human food chain and can affect human health.

Recently (Wring *et al.* 2013) it was found that microplastic pollution impairs the health of the marine worm that helps maintain sediments for other creatures. The reduction of plastic waste, separation of plastic waste for reuse and recycling, improving plastic design and plastic product design, are all essential contributions to help achieve 'zero plastic to landfill' objective. Plastic products and plastic waste are two sides of the same coin and preparation for recycling should start in the product design phase. Designers need to think through the entire life cycle of products including the waste phase. Only 25% of plastic waste is currently recycled in the EU. This is quite alarming considering the dangerous consequences it has on the environment and human health (EU waste: Plastic garbage: from waste to resource, updated Febuary. 2014). Plastic can be recycled and used to manufacture wood plastic composites (Saeed 2013).

Glass waste in Malaysia can also be reused. There is a Malaysian technology which converts grinded glasses into a form of cubes which can be used for water purification thus reducing this waste stream. Recently there has been a strong reduction of demand for recycling of iron, glass, aluminium and paper wastes. There are two main reasons which are interrelated for Malaysia:

- The global financial crises caused the prices of scrap metals to plummet to new lows (Malaysian Recycling, 2008). The prices of some products dropped more than 85%; low-grade scrap metal has plummeted from 80 to 10 sen/kg. This is true not only for iron scrap but also for aluminium and copper.

- The second reason, which also contributes to the first, is that there is minimal separation of waste. Practically there is no separation of glass and aluminium from household waste. There is also no separation of construction and demolition waste to remove iron from wood. Iron separation is done at the melting plant where scrap is melted. There is no applied biotechnology for composting municipal wastes where iron waste is separated by magnetic power.

Paper recycling is less affected compared to other waste because all Malaysian facilities for production of pulp and paper can do recycling of paper waste with minimum additional cost. They just have to separate iron waste particles when the paper is in a form of slurry. Also they pay for collection of paper by collectors who provide house to house service and pay for the paper by weight. (See Malaysia Scrap Market Price Dropped, 2008, Thanam Industry Sdn Bhd: Paper, Recycling Scrap Metal; Why recycling aluminium cans; How scrap is processed).

To reduce the negative effect of waste and to convert waste into resources, Malaysia should promote the separation of waste into four or five categories:

- container for biodegradable (mostly food) waste;
- container for plastic;
- container for glass waste;
- container for metal waste;
- container for paper waste.

All containers must be of different colour. This way Malaysia will have a much bigger volume of separated wastes for economic reuse.

## 5.4 GREEN CITY WASTE

Green waste is biodegradable and in many cases is supplementary to municipal waste for composting. It can consist of park or garden waste such as grasses, flowers, cutting, hedge trimmings.. It can be used for composting separately or together with municipal wastes. Also green waste can be used for biofuel and electricity production. Malaysian cities generate a lot of green waste but unfortunately such waste is not used for composting. In the Netherlands all green waste is collected and transported to one composting centre and composted.

## 5.5 HAZARDOUS WASTE

Biohazardous waste needs to be handled, treated, and disposed of in a very safe manner in order to avoid possible hazards (Wikipedia/a, 2014.File: Hazardous). Such waste includes biomedical home waste and biomedical waste from hospitals which are collected and incinerated. Common producers are: hospitals, health clinics, nursing homes, medical research laboratories, offices of physicians, dentists and veterinarians, home health care and funeral homes. Special equipment is needed to protect workers (Wikipedia, 2014). Existing biohazardous waste treatment technologies perform rather inefficiently, and after treatment, large amounts of residue or by-product are produced, which need to be safely disposed of in a landfill.

Nevertheless, as land availability for landfills is decreasing rapidly, an efficient technology that can maximise the volume reduction of biohazardous waste needs to be identified. Commonly adopted biohazardous waste treatment technologies, such as incineration, autoclaving, and so on, are highly energy-intensive. The high-energy requirement increases the cost of operation quite significantly. The existing biohazardous waste treatment technologies are found to be inadequate from an environmental point of view. As most of these technologies work in a high temperature range, and various waste gases are generated and emitted into the atmosphere, the sustainability of these technologies is often questionable.

Moreover, many chemical treatment technologies involve the usage of toxic and hazardous chemicals, which require treatment before they can be finally discharged into the environment. Treating biohazardous waste using ozone is considered to be the safest approach among all available alternatives. The biohazardous waste treatment technology developed by Ozonator Industries has successfully addressed the above challenges. This technology employs the usage of ozone to safely treat biohazardous waste in an energy efficient and cost-effective manner. This zero-emission system completely eliminates the requirement of by-product or residue disposal. As such, the challenge of land availability and environmental sustainability is efficiently addressed (See: Technology Innovation Leadership Award biohazardous waste treatment North America 2014, 2014; The Waste Incineration Directive; updated February 2014).

## 5.6 E-WASTE

In recent times, enormous amounts of e-waste have been generated globally due to growth of demand for electrical and electronic consumer products. Issues that have arisen concerning e-waste management include insufficient volume due to inadequate collection effort, and lack of legislation governing e-waste. There is also lack of internationally recognised standards for reuse of e-waste (Kissling, *et al.* 2013).

## 5.7 NUCLEAR AND HEAVY-METAL-CONTAMINATED WASTE

Malaysia does not have nuclear waste. Internationally, nuclear waste is separated and disposed in ratherspecialised places, not necessarily in the same country. This waste is under international regulation and the International Atomic Energy Agency is the controlling organ. The mining industry in Malaysia generates soil waste layers which might be radioactive but there is little available information. The contaminated soil layers have to be remediated using chemical and phyto-bioremediation techniques.

## 5.8 INDUSTRIAL WASTE MANAGEMENT

A comparison between developed countries with high waste management rate (EU countries) and Malaysia (**Figure 5.2**) shows that Malaysia with its 5% waste management rate on reuse and recycling needs to put more effort to increase waste management rate to match developed-country levels.

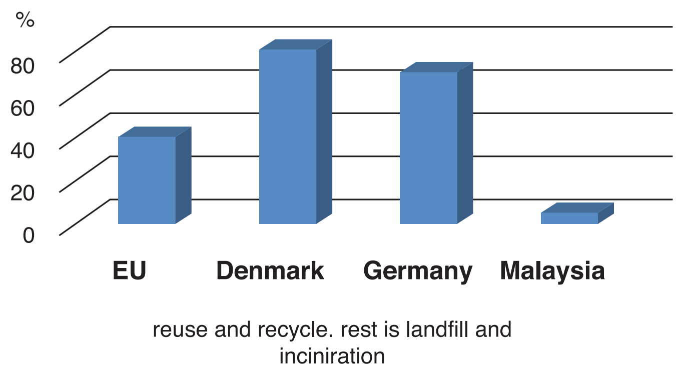



Figure 5.2 Waste management rates (reuse and recycling) in EU and Malaysia

Source : Agamuthu 2010

Note: Roadmap to resource efficient Europe

Shadi Kafi and Mohd Bakri (2012) had observed that Malaysia has a limited number of landfills which contributes to the increase of illegal dumping of waste. They found out that in Peninsular Malaysia, approximately 95-97% of generated solid wastes are transferred to landfills for disposal and just 3-5% of wastes are recycled and processed for other usage. They pointed out that minimisation (reduce, reuse and recycle) of the waste in Malaysian industries would have economic benefits including possibilities of selling specific waste materials besides reducing the volume of industrial waste.

Industrial waste can be classified as general industrial waste that is not hazardous, and industrial waste with hazardous characteristics. The management system and the regulation for each of them is different (DECCW 2009). Hence, they recommend the system in UK to create clubs to develop waste minimisation technologies and to promote environmental regulation. Recently (Europe Press Room, February 2014) published that full implementation of EU legislation will increase the annual turnover of the waste management and recycling sector by EUR 42 billion.

In 1994, waste from industrial activity in Malaysia was 417,413 metric tonnes. In 2009 it increased to 1,705,308 metric tonnes and in 2010 it increased to 1,880,928 (**Figure 5.2**) according to DOE (2010). The key stakeholders in managing solid waste generated by industry are The Ministry of Housing and Local Government, departments of local governments, solid waste contractors and solid waste recyclers (Mohamed 2008). Some problems prevent industries to minimise their wastes (Goh 1990; MHLG 2006ab, Ramesh Babu 2009; Shadi Kafi Bakri 2012). These include low level of awareness, insufficient investments in R&D to develop technologies for waste separation and insufficient effort in composting. Kostov (2008) and Juul *et al.* (2013) reviewed the main optimization tools in the field of waste management and they pointed out that more research is needed which encompasses both recycling and energy solution.

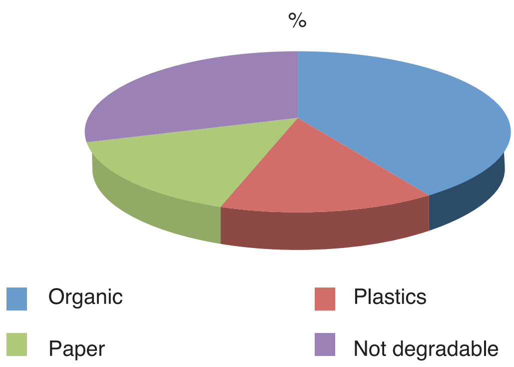



Figure 5.3 Composition of MSW in Malaysia

Source: Agamuthu, 2010.

The Malaysia National Recycling Target is 22% of the total solid waste to be recycled by the year 2020 (**Table 5.1**). The current rate is about 5%. (Agamuthuet. al. 2011). Such low increase from 2-3% reused waste to 5% at present after a series of Government Directives showed that Directives are not supported with strong increase of number, size and suitability of instruments (penalties, measures and incentives). This also based on a recent survey by the Ministry of Housing and Local Government, that found there is 100% awareness among the public, but only 80% are actually practicing them. One important reason for this is insufficiency of facilities, including collection schedule or inappropriateness in the location of recycling facilities. Presently, facilities available are recycling bins, recycling centres, mobile collection units (van), and recycling lorries. A review (Agamuthu *et al.* 2011) has been carried out on the main solid waste management policies in Malaysia namely the National Strategic Plan on Solid Waste Management (MHLG 2005a), the National Solid Waste Management Policy (MHLG 2006bc), the Solid Waste and Public Cleansing Management Act (GOM 2007).

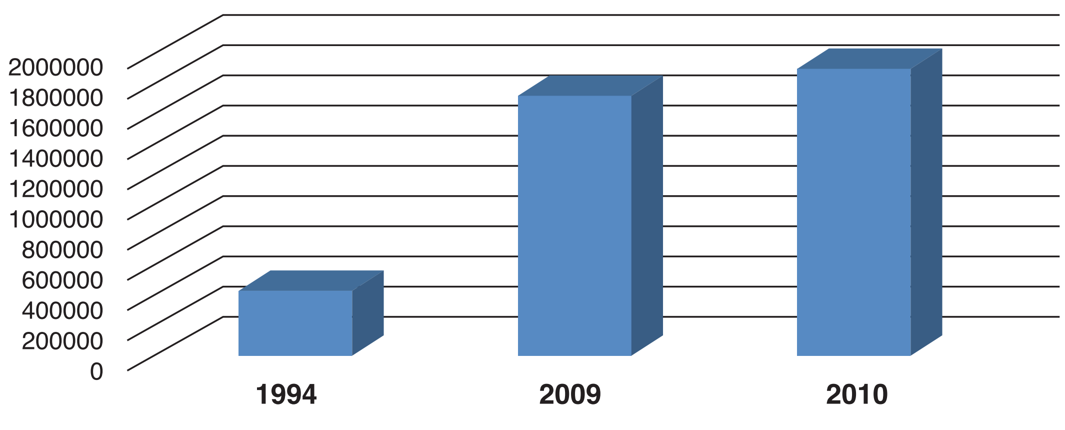



Figure 5.4 Generation of waste from industrial activity in Malaysia

Source: DOE 2010

These policies are the most relevant solid waste management policies on the 3R activities (Reducing, Reuse and Recycling) in Malaysia. The objective of the 3Rs programme is to reduce the national generation of solid waste by reduce, reuse and recycle. The 3Rs gaps between policy and practice were analysed. In conclusion, the study indicated that existing 3R policies have gaps which weaken the implementation of 3R activities, thus resulting in failure of 3R programme in Malaysia. Nevertheless, the National Strategic Plan (NSP) for Solid Waste Management (SWM) provides ambitious targets to improve SWM to year 2020 (**Table 5.1**).

Table 5.1 National Strategic Plan for Solid Waste Management: Targets

| Level of Service | Present | 2003-2009 | 2010-2014 | 2015-2020 |
|---|---|---|---|---|
| Extend collection service | 75% | 80% | 85% | 90% |
| Reduction & Recovery | 3-4% | 10% | 15% | 17%<br>(22%)* |
| Closure of dump sites | 112 sites | 50% | 70% | 100% |
| Source Separation (Urban) | None | 20% | 80% | 100% |

*The reduction target for 2020 was revised by the GOM to 22%

Source: Agamuthu *et al.* 2011

## 5.9 WASTE MANAGEMENT IN KUALA LUMPUR

Kuala Lumpur is the biggest city in Malaysia and special attention has to be paid to its waste management problems. Kuala Lumpur generates 3,500 tons of domestic and industrial waste per day (Bavani 2009). The trend of solid waste generation is expected to reach 30,000 tonnes per day in 2020 (Aziz 2007). Assessment of municipal solid waste generation and recyclable materials potential has been done by Mohamed Osman Saeed *et al.* (2009). Their paper presents a forecasting study of municipal solid waste generation (MSWG) rate and potential of its recyclable components in Kuala Lumpur (KL). The generation rates and composition of solid wastes of various classes such as street cleansing, landscape and garden, industrial and constructional, institutional, residential and commercial were analysed. The study showed that increased solid waste generation of KL is alarming (**Figure5.5**). For instance, the amount of daily residential SWG is found to be about 1.62kg/capita; with the national average at 0.8–0.9kg/capita and is expected to be increasing linearly, reaching to 2.23kg/capita by 2024. It was also found that food (organic) waste is the major recyclable component followed by paper and plastics. For comparison, we have the European Environmental Agency (EEA Chapter 4, 2010) data that municipal waste generation per person in EU-27 Member States was about 524kg per person in 2008, or 1.44kg per person per day; varying between countries by a factor of 2.6.

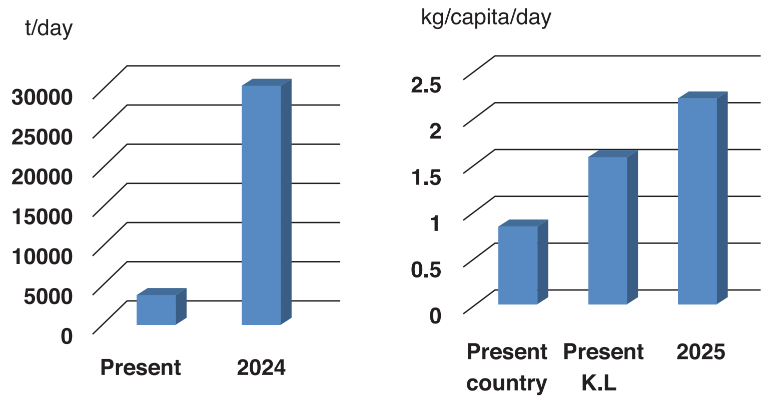



Figure 5.5 Waste generation in Kuala Lumpur

Source: M. Osman Saeed *et al.* 2009

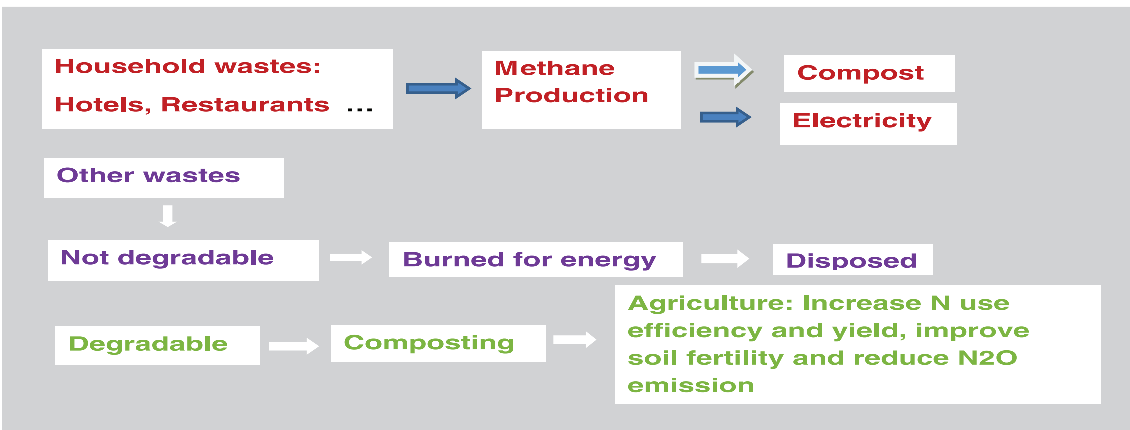



Figure 5.6 Modern municipal waste management concept suitable for big cities like K.L

## 5.10 CHICKEN DUNG WASTE MANAGEMENT

Another very big waste management problem in Malaysia is the production and utilisation of chicken dung. There are few composting chicken dung plants in Malaysia and they cannot manage to treat all chicken dung waste produced. Most producers of eggs or chicken do not have composting plant to prepare compost from chicken dung. As a result, they throw the waste nearby and farmers are taking it to apply to their farms in a row form. Chicken dung applied when it is not composted is very dangerous: it contains too much exchangeable (toxic) heavy metals, too much pathogens, and finally, new viruses can be a serious threat to human health. Added to that, most of the chicken dung composts have the bad smell of methane, rotten eggs ($H_2S$) and ammonia.

This creates bad working conditions in the chicken dung composting plants. The strong odour shows that the composting process is not completely aerobic. There is very bad air circulation and high risk of diseases to workers who work in the plants. Soils after several applications of such composts will drop in pH, accumulate heavy metals after 2-3 years of application and heavy metals will go into crops like vegetables and fruits. Soils acidity has already dropped strongly in Cameron Highlands and the yield has dropped too. There are only a few Malaysian composting plants for chicken dung which meet proper sanitation requirements.

## 5.11 PALM OIL MILL WASTE MANAGEMENT

The palm oil industry waste in Malaysia is enormous in volume and it is toxic to many parts of the environment. At the same time, the palm oil industry is extremely important for national profitability, society, health, security and sustainable economy. For these reasons such waste has to be managed in an appropriate way to protect the income, environment, and sustainability of Malaysia. According to the Malaysian Palm Oil Board (MPOB 2007) about 80 million tonnes fresh fruit bunches (FFB) were processed in 2006. Whereas the amount of palm oil mill waste produced was 17.4 million tonnes of EFB, 53.1 million tonnes of POME (three times higher than EFB), 10.7 million tonnes of mesocarp fibres, 4.3 million tonnes kernel shell and 2.8 million tonnes of decanter solids (**Figure 5.7**).

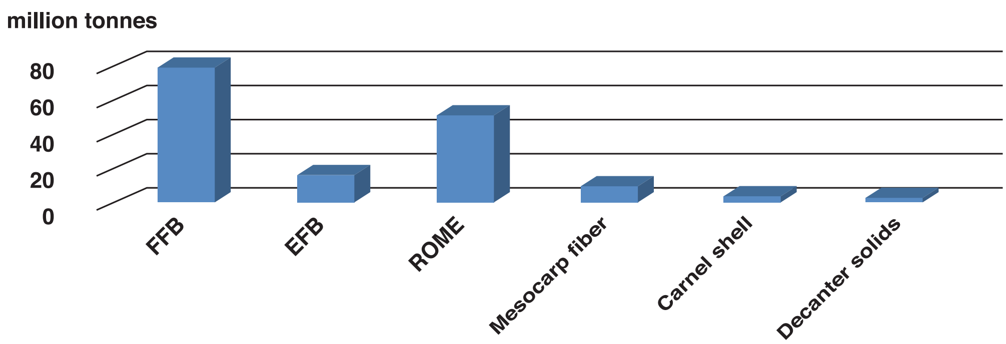



Figure 5.7 Palm Oil Industry products and waste

Source: MPOB 2007

In another publication (Singh *et al.* 2010), it was reported that in 2005 there was a total of 423 mills having production capacity of approximately 89 million of FFB. At the moment the total area of oil palm plantations is 4.917 million ha which make up 67.2% of the total arable land for agriculture of 6.6 million ha. Global demand of edible oils has been increasing in the last few decades, which has resulted in a tremendous increase in the area under oil crop cultivation, particularly for soybean and oil palm, and in waste generation (**Figure 5.8**) (Singh 2010). Fortunately all the palm oil mill industry waste is biodegradable and can be converted into resource easily by using suitable technologies. Some of the mesocarp fibres (about 2.0 million) and kernel shells are used to produce boiler ash and steam for FFB sterilisation and for generation of electricity.

Some of the EFB are used as mulch to protect soil from water erosion and release some nutrients to the palm trees. Some of the EFB are shredded and used as boiler fuel. Some of the EFB are used for making briquettes. Some of EFB are dried and exported and some of this amount is used for production of mattresses. But large amount of EFB are still being dumped in the landfills.

The POME Liquid waste is treated biologically in a pond system or is used for land irrigation. Unfortunately, the capacity of mills has been increasing with years, whereas the size and retention time of the pond systems have not not increased correspondingly, which has resulted in strong contamination of rivers. This discrepancy requires the Malaysian Government to develop new standards for discharged POME and impose sanctions when POME does not meet the new standards.

Both solid EFB and mesocarp waste and liquid waste POME have to be managed with environmentally friendly technologies to convert them into resources. Many private companies, Universities and Institutes in Malaysia have been doing research to develop methods and technologies to find appropriate ways to reuse palm mill oil waste.

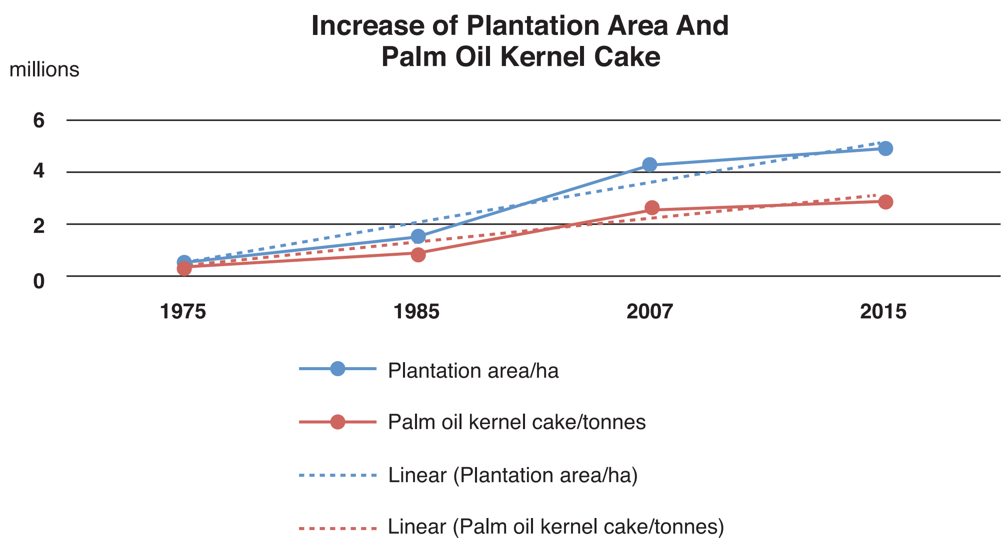



Figure 5.8 Increase in oil palm plantation area and palm oil kernel cake waste

Source: Malaysian Palm Oil Industry

## 5.12 ASSESSMENT OF SOME PUBLISHED TECHNOLOGIES FOR PALM OIL MILL WASTE MANAGEMENT

Patent "WO 2009/131265 A1, 29.10.2008" is very interesting and had been applicable in Malaysia. It used kernel shell, EFB, POME and fibre decanter cake of POME sludge, collected from palm oil mill waste to produce biofertiliser. Biofertilisers are rich in *Bacillus* sp. which can suppress development of plant diseases. Despite that, all methods are acceptable except one which is incineration of EFB to obtain ash. At the moment, traditional incineration of EFB is forbidden in Malaysia. Therefore, this patent is applicable in Malaysia if special incinerators are used.

In efforts of seeking a sustainable solution, the pending Patent: "Zero-Waste Solution Adds Green Earnings for Palm Oil Millers" was presented by Stephen Ng (2012). They used 30% from POME for composting and 70% POME is cleaned by membrane system. They claim that the water is clean and can be released into rivers or recycled in the mill. This technology is extremely expensive for Malaysia as it costs RM50 million. A Canadian company will invest all the money. However, millers are obliged to buy their compost under concession for 10 years. They also produce biogas and supply mill with electricity. Now, the highest requirements are on the sanitation quality (lack of pathogen) of the final product in order to protect human population, soils and plants from diseases. Nonetheless, it is uncertainwhetherthe water from the membrane system is sanitised (boiled, autoclaved, treated with red lights etc.) and would be able meet the present standards.

Nexus Technology Consultancy Sdn Bhd together with MPOB had developed new innovative technology (Patent application Number: PI 2014 0006 21) based on newly patented thermophilic inoculant; tolerant to thermophilic conditions mesophilic microorganisms and for biocontrol properties of the compost, of which*Trichdermaharzianum*. In addition, the technology named "Zero Waste Discharged Composting Technology from all Palm Oil Mill wastes" has been successfully applied. To illustrate, a composting plant was built in Sabah and has been under operation for more than a year, while another composting plant that isalsoinvolvedinprocessingis located in Sabah. There are no any other discharge of POME, EFB and kernel cake disposals and produced compost for one month of composting time, which hasavery low C/N ratio (16), high N content (2.5%), and an extremely high K (7%) content, as well the compost being fully sanitised. The used thermophilicinoculantcontributestothe whole composting process of being under thermophilic (sanitation) conditions. The technology is at times cheaper than RM 50 million. However, the disadvantage of this technology is that it is applicable only to mills with advanced equipment and can absorb as well evaporate up to 55% of POME obtained from FFB processed.

Ooi Ho Seng (2012) reported data that many mills recently started to upgrade their room operation by installing the ECO-D two phase decanter system thus producing significantly less POME reducing up to 45% POME per FFB processed. By installing this equipment Nexus Composting Technology is fully applicable to Mills with upgraded Eco-D system. The total amount of POME produced in Mills can be reduced more up to 0.25 ton POME per ton FFB by replacing the conventional batch steriliser system with the continuous steriliser system.

Dyana Amira *et al.* (2011) showed the performance of strain *Trichodermavirens* as an activator for conversion of EFB and POME into compost. The authors stated that the normal compost takes 4-6 months to mature, however by adding *Trichodermavirens*tothe compost, it matured 21-45 days earlier. Nonetheless, the values of main nutrients are low, despite of the fact that they added chicken dung rich in N to POME and EFB. The N in the compost was 1.304%, while P was 0.5034%, and K was 0.645%.The low percentage of nutrients in the compost indicated that compost was not fully matured. To illustrate, one paper (Wan Rashida Kadir *et al.* 2001) showed that the quality of composts at Malaysian markets are not good and they are not completely matured and their quality is low from sanitation point of view.

Several papers on composting technologies of palm oil mill wastes pointed out the advantages of zero waste discharge approach (Suhaimi & HK 2001; Schuchardt, F, K, Wulfert & Tjahono Herawan 2008; Ooi *et al.*, Kumar 2007; AS, Baharuddin, M, Wakikasa,Y, Shirai S, Abd-Azis, NA, Abdul Rahman & MA, Hassan 2009).

There was a publication on Environmental policy by Global Palm Resources (2012) which was rather detrimental and had a strategic aim. Indonesian authorities decided to change their present policy about POME to be discharged into rivers and EFB to be left in the landfills. They accepted "Zero waste management" policy and will include co-composting of POME and EFB by construction of composting plants. They pointed that it will reduce methane emissions, produce organic fertiliser and reduce expenditure for mineral fertilisers. Additionally the yield increase will bring additional income. They will submit this decision to Roundtable of Sustainable Palm Oil ("RSPO"). RSPO is a not-for profit association which promote the production and use of palm oil in a sustainable for membership manner.

Kostov, O *et al.* (2005) and Kostov and Ngan (2012) had patented innovative composting technologies together with inoculants under Biotop Organic Waste Management Sdn Bhd (in Malaysia and Indonesia). The effect on the FFB yield from recycled (composted) all mill wastes in a field experiment is shown in **Figure 9**.

It can be concluded that the composting segment of recycling industry continues to grow fast. By compost application and increasing N use efficiency by 20%, $N_2O$ emissions will be reduced, saving for 2008-2020 period 23 million tonnes (1.9 million tonnes N/y) of N, financial saving of about $23 (€17) billion/year and the annual benefit to the climate, health and environment could amount to US $160 (€118) billion (500% increase of societal value) (Sutton *et al.* 2013).

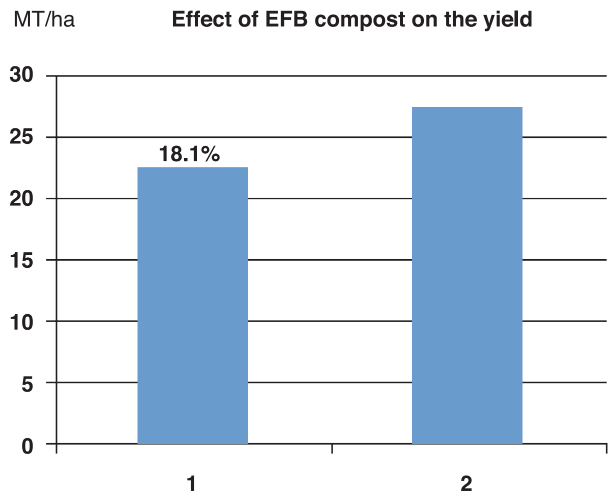



Figure 5.9 Effect of recycled (composted) mill wastes on number and yield of FFB (20 kg/tree/y, in Perak)

Sources: Patents: Kostov O NganT, Y & Ngan H, H (2005) in Malaysia; Kostov, O & Ngan Y (2012) in Indonesia; Paper: Kostov (2008)

Recycled (composted) in suitable way, animal wastes also have positive effect on development and yield of number of crops (Vasileva & Kostov 2001; Vasilava & Kostov 2012; Vasileva 2011). Authors also found that organic fertilisation significantly reduces the water deficiency stress after droughts and recovery of the plants is much faster.

## 5.13 LANDFILLS WASTE FROM PALM OIL MILL INDUSTRY

An important problem for the palm oil industry is the management of existing landfills where EFB, mesocarp fibres and other bio-degradable parts are disposed and greenhouse gases are produced. Our investigations revealed that the leachates which they produce have very low oxy reduction potential (-230 mV) and when leaked into ground waters they produce toxic products. Furthermore, the soils in contact with landfills are contaminated. The decontamination of existing EFB landfills in Malaysia is not a big problem. They just have to be exposed for two weeks in aerobic condition and treated with suitable inoculant to convert them to useful organic fertilisers. So it can be done just with one regulation by the government and all mill landfills in Malaysia will be eliminated and ground water and contacting soil layers will be protected.

## 5.14 INSTRUMENTS FOR COMPOSTING IN MALAYSIA

All of the problems mentioned above for the management of wastes and the composting of wastes are due to the absence in Malaysia of standards for compost quality. Nonetheless, bad composts and good quality composts are sold out at the same price. In contrast, other countries (more than 20 in the world; the UK having several) have Composting Councils which develop standards, make composting policy, make efforts to promote partly or fully organic agriculture etc. In **Appendix II** are shown some activities of such Composting Councils.

## 5.15 LIQUID PALM OIL MILL WASTE MANAGEMENT

POME, that is very toxic, is produced in large volume (**Figure 5.7**, 53 million ton/y) and has bad odour. The present pond systems are not effective enough and their size and retention time (45-65 days) do not correspond to the mill capacity which has been increasing with the time but the pond system has not been increased correspondingly.

Another problem is scum and solid formation at the bottom of pond and also sometimes at the surface which have to be treated and desludged according to the Malaysian Environmental Quality Act (1974). The reduction of BOD to 20 mg/L in Sarawak and Sabah improved the situation in these two areas but still in the discharged points there are ammonium N which is toxic to fishes, tannic acid which is also toxic, Eh (oxy reduction potential) that is not positive in aerobic ponds, salt content that is high, pH is also high and $O_2$ content cannot reach values of 2 mg $O_2$/L to maintain aerobic conditions in aerobic ponds. In the Peninsula the situation is worse with the limit of 100 mg BOD/L which is very high. Therefore, POME is the main problem of the palm oil mill industry and have to be solved urgently. Using the Eco-D two phase decanter cake approach, POME can be reduced to 55% or 45%, as such, more innovative zero waste discharge composting (recycling) technologies can be utilised to remove toxicity from POME, FFB yield will be increased by 8-30% and mineral fertilisers can be reduced thus reducing emission from $N_2O$ which is approximately 200 times more dangerous than $CO_2$ as a greenhouse gas.

## 5.16 ASSESSMENT OF EXISTING TECHNOLOGIES USED FOR POME TREATMENTS IN POND SYSTEMS

There are many technologies for POME purification systems using pond systems as wastewater treatment plant. In order to support performance of pond systems different additional treatments have been engaged. POME, depending on treatment, can be very useful for composting to make organic fertiliser, for production of methane (energy), citric acid, bioethanol, biohydrogen, bioplastic, hydrolytic enzymes etc. (Salihu, Aliyn& Alam, Md. Zahangir 2012). Many pond systems are using different types of filters for removing COD, BOD suspended solids, ammonium nitrogen, turbidity etc. prior to discharge.

This study revealed that a filter of limestone particles removed COD, $NH_3$-N and turbidity by 27.0, 51.3 and 31.5%, respectively. Very promising results are obtained by using zeolite as adsorbent for significant reduction of COD (25-54.6%), BOD, turbidity (80%), Fe, Zn, Mn at lower maintenance cost (M Halim *et al.* 2013; F Ghorbani *et. al.* 2012; Ali Huddin *et al.* 2013, Jalil *et al.* 2010). Zeolite with its high surface, many channels, high ion exchange capacity have wide application as a gas and odour filter. Added to that,itcan remove ammonium nitrogen and rather heavy metals from rivers. Other adsorbents have also attracted attention, like activated carbon, fly ash, peat, lignite, bagasse pith, wood ash, saw dust, periwinkle shells, etc. Very promising treatment of pond system is aeration (O. *et al.* 2010). They discovered that pre-treatment techniques for aeration is the most promising way for biodegradation, sedimentation and removal of phyto-toxicity of POME. Our experiments (data not published) confirmed this conclusion (80% degradation rate of COD for 6 days). Nevertheless, we added selected active microbial cultures for organic degradation. Rupani *et al.* (2010) found that vermicomposting is a good way to convert POME into valuable organic fertilisers.

## 5.17 CHALLENGES IN WASTE MANAGEMENT

All problems mentioned above for managing wastes and composting of wastes are due to Malaysia not having up-to-date standards for utilisation of wastes and corresponding facilities for waste management. Good composts and bad composts are sold without standards for comparisons. There is need to improve connections between obtained research results of Government and private organisations. The guiding concept for waste management should look like the hierarchy in **Figure 11**.

Despite the recent global recession a steady growth of production of municipal solid and all kind of wastes is evident. An estimated 90-95% of MSW in developing countries still end up in landfills. If landfills are not designed properly and are located too near to major cities they have negative impact on human health and the quality of life in general.

It can be concluded that the increasing of the world population by 50% in 2050 (to 9 billion people) and subsequently manufacturing rates and investment in food production, education, health, recycling of wastes will result in pressure to maintain good environmental standards. Therefore, policy-makers in Malaysia have to plan workable targets. Sustainable recycling has to remain as moving target. It is time to open up a discussion and to strive for a post-quantitative level of recycling with all three main purposes namely public health, environment protection and resource conservation.

New standards have to be created, with improved incentives and penalties. In addition, new instruments for more flexible environmental policy have to be applied and new investment to develop technologies for environmental protection to be organised. The cost of waste has to be reflected into the price of materials to increase prevention waste rate. By improving of life time of housing, it will reduce waste generation rate including construction and demolition waste and energy lost. A better waste management will increase resource efficiency use, reduce the impact on environment and will create new jobs. In a recent seminar (BBC 2014) for a selected number of professionals the President of the International Monetary Fund, it was pointed out that two only main challenges related to the growing number of population: (a) the quantity and cost of foods and (b) the increased rate of destruction of the environment.

The assessment of waste environment impact has to be done with new modern methods (Manfredi&Goralzyk 2013). The authors recommended new indicators for environment impact measurement such as climatic change, land use, human health, eutrophication and resource use. Through normalisation and weighting it will enable indicators to be compared in terms of impacts per person and per area. The Life Cycle Analyses (LCA) allows the impact of different waste streams and different management steps, such as collection, landfill and recycling to be evaluated. Additional information and research is needed to determine main waste streams in Malaysia and to characterise type of challenges. Environmental pressures that result from climatic change, biodiversity loss,overuse of natural resources, waste management, pollution and human health have to be addressed as early as possible (See European Environmental Agency Nov 29, 2010, Chapter 6).

As it was mentioned, resources use and waste generation in Malaysia will continue to rise. A life-cycle perspective on natural resources and waste addresses several environmental concerns related to production, consumption and ties together the use of resources and generation of waste which resulted in how to use natural capital to sustain economic development and consumption patterns which appeared to be key drivers of resource use and waste generation (European Environmental Agency Nov 29, 2010, Chapter 4).

Added to that, it is also important to note of how much of resource are used are imported and some of them are linked to other environmental and socio-economic issues. The life-cycle of thinking in waste management contributes to reducing environmental impacts and resource use. Specifically, waste policies can primarily reduce three types of environmental pressures: emissions from waste treatment installations such as methane from landfills, impacts from primary raw materials extractions and air pollution and greenhouse gas emission from energy use in production processes (**Figure 10**).A total approach to waste management may be conceptualised as in **Figure 5.11**.

Recently significant attention is given to a so called circular economy which uses material management, information technologies and business model innovation with the potential to generate USD500 million in material saving and prevent 100 million tonnes of waste globally (Wiebe, February 25, 2014).

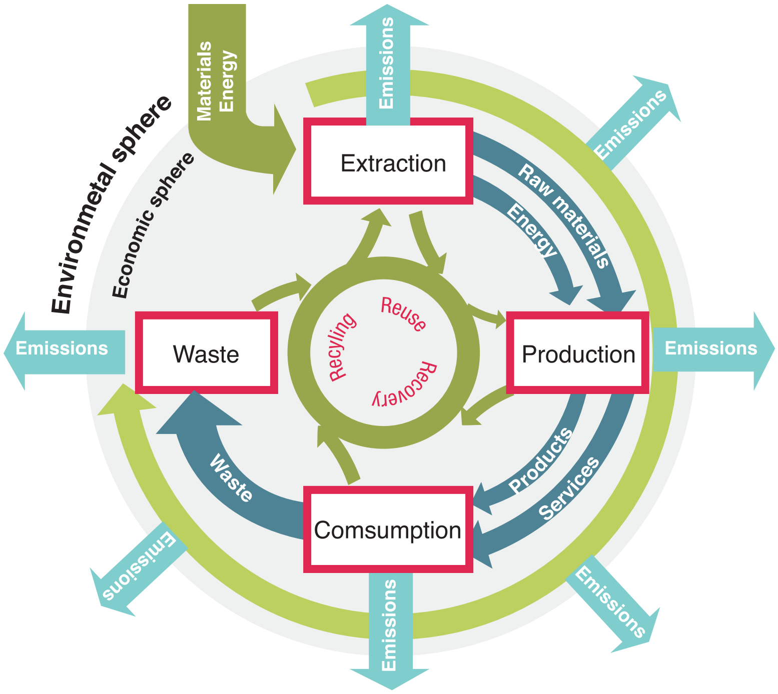



Figure 5.10 Life-cycle chain: extraction — production — consumption — waste

Sources: EEA, ETC Sustainable Consumption and Production

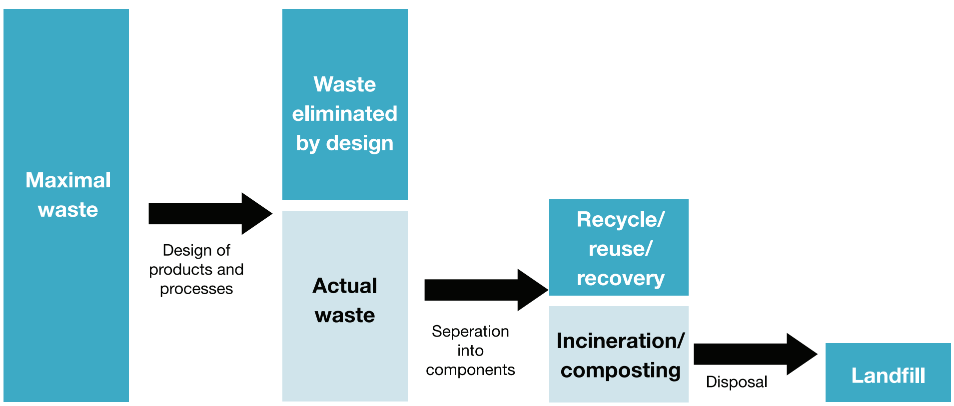



Figure 5.11 Conceptual hierarchy of waste management

Table 5.2 Prognoses for Science, New Technologies, Innovation, Policy and Legislation for Waste Management

| Waste management 2013 | Development of STI opportunities | | |
|---|---|---|---|
| | 2013-2020 | 2020-2035 | 2035-2050 |
| Waste Generation 1.62 kg/ capita<br>Utilisation: 5% | Waste generation 2.23 kg/ capita<br>Separation, sorting, reuse and recycling; composting.<br>Utilisation: 20% | Waste legislation implementation improved. Converting waste to resource. Improved composting and waste to biofuel.<br>Utilisation: 40% | Waste legislation implementation improved. Converting waste to resource. Improved composting and waste to biofuel<br>Utilisation: 50% |
| **Municipal waste (MSW)** | | | |
| Reduction: 5%<br>Separation: 2-4%<br>Recycling: 5%.<br>Waste generation: 28,000 t/ day | Reduction: 10<br>Separation: 15-25<br>Recycling: 22%<br>Waste generation: 38,000 t/day | Reduction: 20%<br>Separation: 25-40%<br>Recycling: 40%<br>Waste generation: 44,000 t/day | Reduction:40%<br>Separation: 70%<br>Recycling: 60%<br>Waste generation: 50,000 t/day |
| Disposal of waste, 95% | Disposal of waste, 80% | Disposal of waste, 60% | Disposal of waste, 30% |
| Waste legislation implementation: 10% | Waste legislation implementation: 15% | Waste legislation implementation: 35% | Waste legislation implementation: 80% |
| Waste to biofuel: 1% | Waste to biofuel: 5% | Waste to biofuel: 30% | Waste to biofuel: 50% |
| **Palm oil mill industry** | | | |
| Empty fruit bunches waste for composting, 5% | Empty fruit bunches waste for composting, 15-20% | Empty fruit bunches waste for composting, 40% | Empty fruit bunches waste for composting, 70% |
| POME used for composting, 2-3% | POME used for composting, 20% | POME used for composting, 40% | POME used for composting, 60% |
| Developing new technologies (Eco-D two phase decanter system for reduction of POME, continue sterilisation, 1% | Developing new technologies (Eco-D two phase decanter system for reduction of POME, continue sterilisation, 10% | Developing new technologies (Eco-D two phase decanter system for reduction of POME, continue sterilisation, 30% | Developing new technologies (Eco-D two phase decanter system for reduction of POME, continue sterilisation, 40% |
| Empty fruit bunches used for disposal to landfills, 70% | Empty fruit bunches used for disposal to landfills, 40% | Empty fruit bunches used for disposal to landfills, 20% | Empty fruit bunches used for disposal to landfills, 5% |
| Landfill waste reduction, 1% | Landfill waste reduction, 35% | Landfill waste reduction, 45% | Landfill waste reduction, 80% |
| Chicken dung composting and utilisation | | | |
| 5% | 10% | 20% | 30% |

## 5.18 CONCLUSION

Despite the recent global recession a steady growth of production of municipal solid waste, palm oil mill wastes and all kinds of waste is evident. An estimated 90-95% of MSW in developing countries still end up in landfills. If landfills are not designed properly and are located near major cities they have negative impact on human health and the quality of life in general.

It can be concluded that the increasein world population by 50% in 2050 (to 9 billion people) together with increase in manufacturing, food production, education, health and waste generation will result in huge pressure to maintain good environmental standards. Therefore policy-makers in Malaysia have to plan workable targets. It is time to open up a discussion and to strive for an advanced level of recycling with three main purposes namely, public health, environment protection and resource conservation.

New standards have to be created, incentives and penalties have to be provided and improved, new instruments for more flexible environmental policy have to be applied, and new investment to develop biotechnologies for environmental protection have to be organised. This is a lot of specialised work and it can be done through Environment Regulatory Agencies and Composting Councils directly under government supervision. The cost of waste has to be reflected into the price of materials to reduce wastage. Improving of life span of housing will reduce waste generation rates including construction and demolition waste and energy lost. It is necessary to increase international cooperation with both developed and developing countries. A better waste management will increase resource efficiency use, reduce the impact on environment and will create new jobs.

Composting technologies for MSW and Palm Oil Industry wastes are the most promising technologies able to solve issues such as reducing waste, reuse of waste, increase yield of food products (oil and fats), increase income and economic growth and reduce contamination of three main components of the environment: air, soils and waters, which will result in a more sustainable society. Initial investment and additional research are needed to enable technological advances without compromising environmental standards. Internationally recognised standards for reuse and recycling of wastes will be very important economic and environment factors forconversion of waste into resources. At the concludingspeech at a seminar (February 2014), the President of the International Monetary Fund pointed out that the world is facing to solve two challenges: (1) to increase the amount of food corresponding to population increase; and (2) to solve the food problem without destruction of the environment.

## 5.19 RECOMMENDATIONS

1. Recognised importance of waste management:

   Ban the organic waste to be disposed in landfill; Developing economic incentives for waste prevention, separation, reuse, recycling; Hiring foreign companies for keys waste management projects;

2. Double tax reduction of companies dealing with wastes, ecosystem priorities, making new modern technological facilities and advances for better waste management;

3. Better interaction between population growth, consumption, generation of waste, compacting materials for disposal etc;

4. Improving legislation policy: encourage product designers to take recycling more important: researchers include collection and sorting as key mechanisms for improving metal recycling;

5. Increase investment in environment protection industry;

6. Need developing recycling-oriented society;

7. Increase knowledge that Malaysia soils are ‘weathered’ soils and needed organic C, N, P to maintain their low level of fertility and to increase the yield and profit;

8. Improving legislation policy: encourage product designers to take recycling more important: researchers include collection and sorting as key mechanisms for improving metal recycling;

9. Organise building of modern municipal waste management centres suitable for big cities like K.L.;

10. Creating Environment Regulatory Agency and Composting Council attached directly to the Government. New Environmental bodies to develop: improve old and develop new standards, improve incentives and penalties, create new instruments for more flexible environmental policy; new investment to be planned to develop new technologies for minimisation of wastes;

11. All biodegradable part of MSW and from other industrial wastes have to be composted and the rest to be converted into energy;

12. Remove all landfills attached to Mills and all chicken dung generated must be composted;

13. Palm Oil Mill Industry Wastes can be eliminated the most effectively by Zero Waste Discharged Composting Technologies thus eliminate waste, protect fully environment, bring the highest income and contributed for sustainable Malaysian society and Environment;

14. Financial stimulus for these Palm Oil Mills which is going to introduce Eco-D system or continue steriliser system which reduce the volume of liquid waste POME by 25-40%;

15. Introduce standards for discharged POME at 20 mg BOD/L in Peninsula Malaysia to be like other Malaysian States and discharged POME to have at least 2 mg $O_2$/L;

16. To build a coherent strategy to optimise plastic waste policy and effectively addressed waste legislation;

17. To develop effective protection of environment, correct use of natural resources, high level of economic growth and good waste management practices which are the main components of sustainable development of Malaysia. It can be done by converting wastes into resources; and

18. Landfills have to be modernised to prevent or reduce the adverse effects of the landfill of waste on the environment, in particular on surface water, groundwater, soil, air and human health.

They have to be categorised properly to: landfills for hazardous waste; landfills for non-hazardous waste; landfills for inert waste. This is to develop waste acceptance for proper waste disposal that avoid any risks occuring:

- waste must be treated before being landfilled;
- hazardous waste within the meaning of the Directive must be assigned to a hazardous waste landfill;
- landfills for non-hazardous waste must be used for municipal waste and for non-hazardous waste;
- landfill sites for inert waste must be used only for inert waste;
- criteria for the acceptance of waste at each landfill class must be adopted.

Nevertheless, the following wastes may not be accepted in a landfill:

- liquid waste;
- flammable waste;
- explosive or oxidising waste;
- hospital and other clinical waste which is infectious;
- used tires, with certain exceptions;
- any other type of waste which does not meet the acceptance criteria

19. To prepare regularly information on the main available statistics on waste generation and management – a summary of the main forthcoming challenges and recommendations for future actions; to study the use of economic instruments and their possible impact on the accepted waste hierarchy;

20. To prepare EIA for waste disposal and management projects prior to their approval or authorisation. Consultation with the public is a key feature of environmental assessment procedures

21. Assessment of waste environment impact has to be done with new modern methods. It is recommended that new indicators for environment impact measurement should include climate change, land use, human health, eutrophication and resource use. New classification and characterization as first steps have to be done by using chosen indicators such as climate change, impact on ozone levels and impact on eutrophication. Normalised and weighting as second optional steps will allow indicators to be compared in terms of impacts per person and per area. Thus, LCA allows the impact of different waste streams and different management steps, such as collection, landfill and recycling to be evaluated. For the EU, the most important are the climatic change and fresh water eutrophication impacts caused by methane and $CO_2$ associated with household and similar wastes in landfills and waste incineration plants.

# CHAPTER 6
## LAND AND FORESTS

This chapter on land has been expanded from the original theme of Natural Resources. The term Natural Resources also covers water and energy resources as well as biomass, which is currently a part of the waste issue. We have redefined the topic to cover forests, but forests cannot be discussed without reference to land policies and land management and capability classification. The chapter will now cover land, forests, and terrestrial biodiversity.

The key issues in the management of land are: (a) the way land is allocated for different land uses, (b) the strength of national commitment to the maintenance of forest cover for timber production and conservation of terrestrial biodiversity, (c) the growing importance of forests and plant cover in general as a terrestrial carbon sink; and (d) forests as places of adventure. Malaysia can do a lot more as a carbon sink by promoting tree planting in urban areas and underutilised lands outside of the designated forest reserves, and as renewable energy in the form of wood pellets for internal use and export to replace fossil fuels and as horticultural carbon for carbon sequestration.

### 6.1 CONCEPTUAL BACKGROUND: THE MANAGEMENT OF LAND IN MALAYSIA

Peninsular Malaysia had its own system of land tenure. Thus is the case for Sarawak and Sabah. The country, Malaysia had observed the system of land tenure which was based on the customs of its people. With the arrival of the British in Peninsular Malaysia (then Malaya) the system which the country was accustomed to had undergone an abrupt change. Land tenure and its administration were also affected as new laws were enacted relating thereto. The laws introduced and the development pursued by the new masters has in one way or the other affected the subdued local inhabitants (HjhSiti Maryam 1999).

## 6.2 COLONIAL RULE, POSTCOLONIAL RULE AND THE NATIONAL LAND LAWS

One peculiar thing that prompted the British colonial rule was the promising natural resources they could extract from a country, such as Malaysia. In the case of Peninsular Malaysia, the main purpose of the British was to secure and exploit the tin and other mining resources in the Malay States, particularly Perak and Selangor.

When the British extended their rule in the last quarter of the 19th century, they set up the 'Residential System', whereby each Malay State was assigned a British Resident who would then assist and advice the Malay Ruler/ Sultan in matters related to the respective State. In reality, however, the Sultans were reduced to a petty heads as it was indeed the Residents who held the power as the Sultans were bound to follow the Residents' advices. The intervention by the British had opened up the country for the entry of the capitalists (Sundram 1988). Sundram further noted that tenancy and share-cropping emerged as a result of the colonial land laws and policies that favoured the interest of capital.

The colonial intervention in Peninsular Malaysia had created the conditions for landlordism and its corollary, peasant tenancy, and likewise, facilitated the proletarianisation of the poor peasants. Before the British colonisation of Malaya, access to the use of uncultivated land was not constrained by law, but since the advent of the British, land was transformed into a commodity to be owned and transacted, over which the State ultimately controlled access (Siti Maryam 1999).

In the case of states Perak and Selangor, the Sultans issued similar Proclamations upon the advice of the British Residents respectively, but the Malays were not totally stripped off of their lands as the British had enacted the Malay Reservations Land Enactment in order to protect the Malays from losing their lands to the money lenders who were non-Bumiputra. Inevitably, owing to the prevailing situations under colonial rules, Malaysia had enacted laws that breathed and embodied the substratum of the legal notions and principles of the colonial powers

## 6.3 TORRENS SYSTEM

First and foremost, Malaysia adopted the Torrens system where registration is the key to the land title. The 'Torrens system', named after Sir Robert Torrens and introduced in South Australia in 1858, is perhaps the best known system of title registration. The introduction of a Torrens system in Malaysia was a slow and complex process spreading over a long period of time. In Malaysia, the Torrens system of land legislation was introduced during the British colonial rule through W.E. Maxwell after his return from Australia to observe the land tenure system there, which he found to be suited to the Malaysian land tenure system (ibid.).

Apart from the Torrens system, the Malaysian land law has also been influenced by Islamic law and customary law. The reason for the influence of Islamic law is not difficult to understand. Since the establishment of the Sultanate of Malacca in 1400, the locals (the Malays) have been professing the religion of Islam, a characteristic that remain until after independence. Although the Malaya States were occupied by various countries for 446 years, they were not occupied comprehensively (with the exception of the short period of Japanese occupation) and autonomy largely remained. The policy of various States was mostly one of 'non-interference' and the Sultans or local leaders had de facto control over land matter.

After the British occupation, common law and equity principles were introduced into the Federated Malay States (FMS) as new sources of land law, in addition to the local customary land tenure. Moreover, the laws governing land in these FMS were characterised by the Torrens system, instead of Islamic land law. The four States of Perak, Selangor, Negeri Sembilan and Pahang, which later became the FMS were the first to enacted laws introducing Torrens title for use in a Malaysia setting. Title registration system was first introduced in Perak by way of General Land Regulation 1879; in Selangor General Land Regulation 1882, in Negeri Sembilan General Land Regulations 1887 and in Pahang General Land Regulations II 1889. By 1911, a unified Federated Malay States land enactment was passed.

## 6.4 LAND OWNERSHIP UNDER THE FEDERAL CONSTITUTION

In Malaysia, the right to own properties is given and protected under Article 13 of the Federal Constitution, i.e. (i) no person shall be deprived of property save in accordance with law; and (ii) no law shall provide for the compulsory acquisition or use of property without adequate compensation. Due process does require that the State Government at the minimum give the owner prior notice of the confiscation plan and a meaningful opportunity to be heard before the land in question can legally be confiscated of its vested property rights.

The procedures are constitutionally mandated “to promote social justice, ensure the dignity, provide welfare and security of all people and equitable diffuse property ownership”. After all the formalities are satisfied the Government can proceed to take the land, but just or adequate compensation (fair and reasonable to both parties) must be made (Siti Maryam 1999). In case of compensation disputes, the owner of the land may contest under Section 37(1) of the Land Acquisition Act, 1960, or bring the matter to the court through an appeal.

### 6.4.1 LAND OWNERSHIP UNDER THE NATIONAL LAND LAWS

Under the National Land Code (NLC) 1965 the concept of land ownership is connected to the and related to the concept of the indefeasibility of title, as derived from the Torrens system – a system of land registration which establishes and certifies under the authority of the State Government, the ownership of an indefeasible title to land and simplifies, hastens and cheapens all dealings thereof (Hajah Siti Maryam 1999). Registration is the key to the title and hence makes the registered owner the land proprietor and the legal owner of the said land. With the adoption of the NLC 1965, the previous land laws were consolidated into one unified law and this eventually brought changes and improvements in the land ownership policy.

Currently, the law that regulates land in Peninsular Malaysia is the NLC 1965. The NLC 1965 was made effective from 1st of January 1966, whereby henceforth a uniform system of land tenure and dealing existed throughout Peninsular Malaysia. Penang and Malacca were also absorbed into the system by the promulgation of the National Land Code (Penang and Malacca) Titles Act 1963.

The operations of the NLC 1965, which provides for the Torrens system of title is supplemented by the various subsidiary legislations enacted and passed by the respective State Governments in Peninsular Malaysia. After the formation of Malaysia in 1963, the Federal Constitution was amended to include special provisions applicable to the States of Sabah and Sarawak. Some Federal Acts of Parliament apply differently to these States on a number of matters such as Acts related to immigration, land and natural resource management. For instance, in the Peninsular, the *National Land Code* governs most of the laws relating to land. In Sabah, the main legislation is the *Sabah Land Ordinance*; and in Sarawak, the *Sarawak Land Code*. Therefore, the State Authority can alienate and dispose of land within its territory in a manner prescribed by the various laws, e.g. National Land laws, Mining Law Act and the Forest Enactment/ Act.

## 6.5 GOVERNMENT POLICIES REGARDING LAND USE AND FORESTRY

### 6.5.1 FOREST LEGISLATION

Forest legislation in Peninsular Malaysia has been in practice since 1930 when the various forestry enactments and rules were formulated by the respective State authorities. These were found to be deficient and weak in areas of forest management planning and forest renewal operations which are vital to sustained yield management. In order to overcome these short-comings, the National Forestry Council (NFC) agreed to review, update and make uniform the existing State Forest Enactments so as to streamline forest administration, management, conservation and forestry sector development in the country. Hence, the National Forestry Act and the Wood-Based Industries Act were formulated. These were passed by an Act of Parliament in October 1984. Apart from the National Forestry Policy and other forestry legislations, the Federal government has enacted laws pertaining to timber trade, research and development, land conservation and environment quality.

Forest activities in Sabah are regulated by a Forest Enactment 1968. Forestry practices in Sarawak involve not only the regulation and management of the forest resources but also the protection and management of National Parks and Wildlife Sanctuaries. Thus, in Sarawak, the Forest Department has jurisdiction over all the permanent forests, national parks and wildlife sanctuaries. These activities are regulated by the following legislative documents (i) Forest Ordinance (Sarawak Chapter 126), (ii) National Parks Ordinance (Chap. 127), and (iii) Wildlife Protection Ordinance (Chap. 128).

### 6.5.2 FORESTRY POLICIES IN MALAYSIA

The first notable official statement of forestry policy in 1922 stated that “the forests properly managed are an asset of continually increasing value and the Government attaches the greatest importance to their maintenance, not only as a source of revenue, but on account of the many other benefits accrue from the possession of them” (Anon 1959).

In 1937, the country was criticised for trailing the lead of India, the pioneer in British forest conservation, too blindly. As such, the adoption of the term "Reserved Forest" and "Forest Reserve" in which give rise to many misconceptions. It also implies “*an area of forest that is being kept in cold storage by the Government until such time it can be intensely logged, after which it will be useless for further timber production and can be revoked and alienated”.* It was argued that if the “*policy to retain permanently under forest a sufficient area of land to meet all the country’s internal needs for forest produce and to protect the steeper hill sides from erosion*” is to be better understood and accepted, the permanent forests should be known by the more appropriate and descriptive title of “State Forest”, something after the style of the French ForetDomaniale or the German Staatforst (Menon 1976).

An **Interim Forest Policy for the Federation of Malaya** was prepared in 1952. It received official support and was accepted as a working policy but was not then adopted as the official national forestry policy (Anon 1959)[1]. **Sarawak’s Statement of Forest Policy** was approved in 1954 and remains in effect (Anon 1954). The policy was issued and provides for the reservation of a permanent forest estate for protection and production, sustainable management of the productive forests, economical utilisation of forest products, and promotion of exports. Sabah promulgated forestry policies for forest management, planning and implementation to ensure that the forest as a renewable resource is maintained and managed properly. The debates to amend and improve the **Interim Forest Policy for the Federation of Malaya** took place between 1955 until 1959.

In 1969, the National Land Council approved an **Interim National Forest Policy for Peninsular**

**Malaysia.** In the same year (1969) a draft **National Forestry Act** was prepared and revised in 1973 to provide for necessary administrative and legal mechanisms to give effect to the forestry policy and for integration and harmonisation of forestry activities in Peninsular Malaysia (Anon 1973). Following independence in 1957, with Sabah and Sarawak joining the Federation in 1963, Malaysia developed rapidly through the conversion of natural forests to rubber, oil palm, and cocoa plantations in response to the demand for tropical hardwoods and primary commodities from the developed countries. Forestry continues to feature prominently in many Malaysian plans (5-year Malaysia Plan), the Second Outline Perspective Plan, and the National Development Policy to enable Malaysia to achieve VISION 2020.

### 6.5.3 THE NATIONAL FORESTRY POLICY 1978 (REVISED 1992)

See **Appendix 1**.

## 6.6 FORESTRY REGULATION AND ADMINISTRATION

### 6.6.1 FORESTRY ADMINISTRATION

Malaysia will "ensure that her invaluable resources are not wasted. The land must remain productive and fertile, the atmosphere clear and clean, the water unpolluted, the forest resources capable of regeneration - able to yield to the needs of the nation's development. The beauty of the land must not be desecrated: for its own sake and for economic advancement." So is stated in the Malaysia's Vision 2020.

These forests are gazetted in accordance with the National Forestry Act, 1984 (Amended 1993) in Peninsular Malaysia and the relevant State forest ordinance/ enactment in Sabah and Sarawak. A significant proportion of the total PFR (i.e. natural forests and planted forests combined) has been demarcated on the ground. Licensed land surveyors mark the boundaries of the PFR by the placement of permanent boundary stones.

Detailed information about the ownership arrangement of forestlands in Malaysia is rarely published in the public arena – though it need to be noted, currently, all gazetted forestlands in Malaysia are owned and managed by the State Governments, while small patches of forestlands in Sabah and Sarawak are claimed as indigenous customary right lands and some forest plantations are privately managed. Although the management of all natural forests is under the purview of the respective State departments of forestry, state governments do lease forestlands out to integrated timber companies, at various lengths; giving long-term concession tenure for 30-60 years. In Sabah concession tenure involves about 100,000 hectares for a period of up to 99 years (Gregesen *et al.* 2004). The management of leased forestland has to be guided by their forest management plans approved by the State Department of Forestry.

As mentioned earlier, the management of the forests is considered a State matter, and forests come under the jurisdiction of State Governments, while Federal Government agencies provide technical assistance, advice and development aid. When the State of Sabah decided to lease the forestland to private companies it created forest management units (FMU). Each FMU is required to have a management plan. The plan has to describe in details what actions will be performed within the concession and how this would affect the forest resource overall. Some forest areas in Sarawak are allowed to be earmarked for plantation development, and in Sabah, there are degraded areas that are also earmarked for plantation development.

### 6.6.2 ADMINISTRATION OF FOREST USE

Following comprehensive land use in Malaysia, about 56% of land area, exclude rubber and oil palm plantations, is today still covered with indigenous forests. Legally, various forest land classifications were gazetted in accordance with the following important legislations:

(1) National Forestry Act 1984;

(2) National Parks Act 1980;

(3) Wildlife Conservation Act 2010;

(4) Sabah's Forest Enactment 1968;

(5) Sabah's Parks Enactment 1984;

(6) Sabah's Fauna Conservation Ordinance 1963;

(7) Sarawak's Forest Ordinance 1954 (Cap. 126): Forest Rules 1962/ The Forest (Planted Forests) Rules 1997;

(8) Sarawak's National Parks and Nature Reserve Ordinance 1986;

(9) Sarawak's Wildlife Protection Ordinance 1998 (Cap 26): Wildlife Protection Rules 1998; and

(10) Various State Laws: State Forest Enactments/ State Forest Rules/ State Ordinances related to protection of wildlife.

Other legislations and policies have strengthened the implementation of forest land classifications, e.g. the National Forest Policy 1978, Environmental Quality Act 1974 (Environmental Impact Assessment Order 1987), National Policy on Biological Diversity 1998, and National Policy on Environment 2002. Over the period 1970 to 2000 natural forest, the storehouse of biodiversity, was reduced by about 20% in the whole of Malaysia, mainly in conversion to the cash crops, oil palm and rubber.

In 1992, the National Forestry Policy 1978 (NFP) was revised to include the conservation of biological diversity, the sustainable utilisation of forest genetic resources, and the role of local communities in forest development. To ensure effective forest management and implementation of the NFP in Malaysia, State authorities have been formulating and enforcing various acts and ordinances since the early 1900s. Forest management planning and operations were further streamlined and strengthened with the adoption of the National Forestry Act 1984 (NFA) and the National Timber Industry Policy (NATIP) 2009-2020. Similar to the NFP, the NFA was amended in 1993 to incorporate additional provisions related to sustainable forest management, by way of more stringent penalties for violations, including the illegal felling of trees, and to provide for mandatory imprisonment of convicted offenders. The police and armed forces were given new powers of surveillance in the forestry sector, with the aim of curbing illegal logging, encroachment, and timber theft.

In December 2007, the Parliament approved Malaysia's International Trade in Endangered Species Act 2008 to legislate the administration and management of international trade in wild fauna and flora so that it does not threaten the survival of any species of wild fauna and flora in the country. Other examples of legislations of importance to the forestry sector are:

- Mining Enactment 1926
- Water Enactment 1935
- Aboriginal Peoples Act 1954
- Land Conservation Act 1960
- National Land Code 1965
- Malaysian Timber Industry Board Act 1973
- Local Government Act 1976
- Malaysian Forestry Research and Development Board Act 1985

- Penal Code (FMS Cap. 45) 1948
- Evidence Act 1950
- Financial Procedure Act 1967
- Occupational Safety and Health Act 1994
- Criminal Procedure Code (FMS Cap.6) 1903
- Protection of New Plant Varieties Act 2004
- Biosafety Act 2007
- Sarawak River Ordinance 1993/ Sarawak Water or dinance 1994
- Sabah Water Resources Enactment 1998/ Sabah Biodiversity Enactment 2000

## 6.7 FOREST LAND USE AND LAND USE CHANGE IN MALAYSIA

### 6.7.1 HISTORICAL PERSPECTIVE

Natural forests were once extensive in Malaysia. Contrary to events in other regions of the world, European colonisation of Malaya, which began in 1511 with the capture of Malacca by the Portuguese. However it did not result in exploitation and removal of the forest. In those days, the foreign demand was for “minor forest products” - spices, gum Arabic, and gutta-percha. Exploitation for timber began in earnest only towards the end of the 19th century. The logged timber was entirely used for development within Malaya, in construction work, the building of the railway lines and for tin mining and smelting. This period also saw an unprecedented demand for gutta-percha, an exudate that resembles latex from *Nyatohtabanmerah* (*Palaquimgutta*). This substance was needed for the insulation of the sea cables used in pre-wireless days. This resulted in heavy exploitation of the *Nyatohtabanmerah* trees from the forests. Another development of the time that affected forests was the introduction of rubber (*Hevea*) plantations.

Export of timber did not really take place until the Empire Trade Fair Exhibition of 1925. Samples of Malayan forest produce and timber samples were sent to London. This was when interest for Malayan timber was shown and a market for it began to be established. In those days sustainable forest management was never heard of, and uncontrolled logging and heavy exploitation were the rules. In 1947, post-war examination from selective felling of forest was done and it showed that many areas contained adequate or even abundant regeneration of timber species (Walton 1948). These areas on the whole would recover by themselves. This observation led to the development of the Malayan Uniform System (MUS) for managing the lowland Dipterocarp forests in Malaya.

However, in 1960, the ‘Malayanisation’ process began and by 1963, based on the Ford Foundation report, plans for agricultural diversification and rural development were initiated in Peninsular Malaysia. Before the decade was over, sweeping changes to land-use policies were made and most of the timber-rich lowland forests were set aside for agriculture. Forestry was third priority after mining and agriculture for land-use. Forestry was forced up to the hills and those areas with soils too poor for agriculture, and where the forest composition and its merchantable value did not measure up to that in the lowland Dipterocarp rich forests (see Land Classification Class in later chapter). In Sabah and Sarawak, too, apart from uncontrolled logging, forest had been lost due to shifting cultivation using the slash and burn method by the natives.

Hence, beginning in the early 1960s, large tracts of lowland forest were cleared for the planting of paddy and rubber under the country’s agricultural development program. Millions of hectares of rubber plantations have been established since then. Tin mining became big business and large areas of inland lowland forest containing tin were licensed for mining. After mining, these areas were almost void of any vegetation. Around the early 1970s oil palm was also introduced into commercial planting and again vast tracts of lowland forest were taken up for this plantation crop. Today, it can be seen that most of Malaysian forests are confined to the hills. Then again around the 1990s, the country experienced the industrialisation era where large tracts of forest were cleared for mixed developments - low cost housing and industrial buildings. Forests areas in Malaysia had undergone a State of transition (see **Section 6.5**).

## 6.8 CURRENT LAND USE AND LAND TENURE ARRANGEMENT[2]

Malaysia is rich in natural resources and commodities. It produces petroleum and is a net exporter. Malaysia also produces liquefied natural gas as well as various other related products, most of which are found off the coasts of Terengganu, Sabah, and Sarawak. Other commodities explored and extracted are tin, petroleum, timber, copper, iron, ore, natural gas, bauxite. Malaysia was the largest exporter of tin until the industry wide collapse in 1980s. Tin deposits are still found in Selangor, Kinta valley in Perak, Pahang and Johor. There are significant deposits of gold in Pahang towns of Raub and Kuala Lipis and also Kelantan's district of Gua Musang. Coal is mostly concentrated in Sarawak town of Kapit, Mukah and Silantek. Added to that, Malaysia is one of the largest exporters of palm oil and rubber and their products in the world. Malaysian also continues to be an important exporter for timber and other timber products.

**Table 6.1** shows that, at the end of 2005, an estimated 18.31 million ha (55.8% of total land area) was forest. Land under perennial tree crops such as rubber, oil palm, cocoa and coconut totalled 5.55 million ha (16.9%), and land used for other purposes such as settlements and infrastructural development amounted to 8.97 million ha (27.3%). If 5.55 million hectares of tree crops - which are similar to reforested land and are increasingly looked upon as alternative sources of wood supply, especially rubberwood, were counted as part of the area under tree cover, it would increase to 23.86 million ha or 72.7% of Malaysia's total land area. A typical land use pattern is shown in **Appendix 2** (Peninsular Malaysia).

Table 6.1 Land Use Patterns by Region in 2005 (Million Ha)

| Region | Land Area | Natural Forest | Forest Plantation | Agricultural Tree Crops | Other Land Uses | Total Forest Area | Percentage Total of Forest Area |
|---|---|---|---|---|---|---|---|
| Peninsular Malaysia | 13.16 | 5.81 | 0.07 | 3.32 | 3.96 | 5.88 | 44.7 |
| Sabah | 7.37 | 4.16 | 0.20 | 1.50 | 1.51 | 4.36 | 59.2 |
| Sarawak | 12.30 | 7.94 | 0.13 | 0.73 | 3.50 | 8.07 | 65.6 |
| Malaysia | 32.83 | 17.91 | 0.40 | 5.55 | 8.97 | 18.31 | 55.8 |

Source: Samsu 2010

## 6.9 LAND USE CHANGE AND LAND CAPABILITY CLASSIFICATION AFTER 1970

The Land Capability Classification (LCC) used soil fertility as a criterion of land-use in the country. This implied that a large portion of the present productive lowland forests have to be surrendered to agriculture, and productive forestry will be confined largely to land unsuited to permanent agriculture - land unlikely to be carrying highly productive natural forest. The LCC established five classes of land and recommended economically best uses for each.

Mining (mainly for tin) and agriculture were deemed more valuable in Classes I-III, which comprised the better-quality land in the lowlands and on gentle slopes, while forestry was assigned to the poorest land, in Classes IV and V. These two classes covered about 40% of the Peninsula, but they were largely restricted to inland freshwater swamps and upland areas. Swamps were later reassigned to Class III, leaving forestry with only the uplands (Salleh 1972). In short, the LCC provided some assurance of a permanent forest base, but it did not include the fertile lowland forests. The LCC was essentially an application of the economic concepts that assigned land uses to capability classes; it focused on the “added value due to the use of the land and did not consider secondary processing industries” (Salleh 1972).

According to the classification, forestry did not belong in Classes I-III because it generated lower rents than competing uses, but it did belong in Classes IV-V, where it generated higher rents. Numerous studies have determined that rubber and oil palm plantations established during the 1960s and 1970s by the Federal Land Development Authority (FELDA) and private plantation companies did indeed earn high rates of return (Vincent & Yusuf 1993). Agricultural area expanded and forest area shrank. Agriculture received another policy ally in the form of the National Economic Policy (NEP), established after 1969 with its emphasis upon alleviating rural poverty. In fact, land development showed no sign of slowing down at the start of the 1970s. Land use changed in the 1970s to 1980s continued to be guided by the LCC. Deforestation in the 1980s continued to be driven by perceived returns to agricultural expansion, with the Forestry Department’s efforts to prevent conversion providing only minor resistance.

If there was a reasonable request to alienate forests for some form of development, the states generally granted it. Nevertheless, despite that, by the late 1980s the rate of conversion was slowing, as industrialisation and urbanisation caused the rural labour market to tighten and agricultural returns to fall. Most striking was a statement in the *Sixth Malaysia Plan* 1991-1995 that, except for projects in-progress, FELDA would develop no additional land during the period covered by the *Plan.*

## 6.10 DEFINITION OF FORESTS

See **Appendix 3**.

## 6.11 FOREST COVER CHANGE AND CURRENT EXTENT OF FOREST

As much as the Government of Malaysia pledged to ensure that at least 50% of its land remains permanently under forest cover (see **Figure 6.1**), forest area of IMalaysia had been in a state of flux: from 20.10 million hectares in 1988 to 20.46 million hectares in 2010, then fluctuated in hectares between the years 1989 to 2011 as shown in **Table 6.2** below.


Figure 6.1 Distribution of tropical rainforest in Southeast Asia and Relative Position of Malaysia

Table 6.2 Changes in Forest Area: Malaysia

| Year Hectare (%) | Year Hectare (%) |
|---|---|
| 1988 ~ 20.10 mil ha (61%) | 2003 ~ 19.54 mil ha (59%) |
| 1989 ~ 19.47 mil ha (59%) | 2005 ~ 18.31 mil ha (56%) |
| 1992 ~ 19.15 mil ha (58%) | 2007 ~ 18.23 mil ha (56%) |
| 1994 ~ 19.00 mil ha (58%) | 2010 ~ 20.46 mil ha (62%) |
| 1996 ~ 18.87 mil ha (57%) | 2011 ~ 18.48 mil ha (56%) |
| Implementation of National Forestry Policy 1978 (Revised 1992). | Gazettement of National Forestry Act 1984 (Amended 1993). |

In many developed countries, the area of forest is now increasing after long periods of decline. The change from shrinking to expanding forests has been termed as the forest transition (Grainger 1995). It is quite difficult to categorise Malaysia as having forest transition or otherwise due to its fluctuating forest areas as presented above. However, if one broadens the perspectives of forest transitions to include, among other "a change in emphasis from production to protection and conservation, a shift from unsustainable to sustainable forest management and even a societal transition or a cultural change for the better forest management, utilisation and conservation", then Malaysia can be considered as transiting towards a sustainable forest management

### 6.11.1 FOREST RESOURCES AND SCARCITY OF FORESTS

Malaysia is fortunate to be endowed with vast stretches of evergreen tropical rainforests – a natural heritage rich in plant and animal life. The Malaysian tropical rainforest is one of the most complex and species – rich ecosystems on planet earth. With more than half the country clad in forests, home to an astonishing diversity and abundance of living plants, animals, insects, fish and reptiles, Malaysia recognises the need to manage its forests for sustainable yield of economically valuable timber that will not put at risk environmental stability and ecological balance. A typical hill forest in Malaysia is shown in **Figure 6.2** (see also Appendix 4 – Main Vegetation/ Forest Type Maps in Peninsular Malaysia, Sabah and Sarawak).

Malaysia reports its forests according to three major forest categories: Permanent Reserve Forest – PFR (or Permanent Forest Estate - PFE); State/ Alienated forest; and National Park & Wildlife/ Bird sanctuary. In 2011, Malaysia has about 14.61 mil ha of PFR (Peninsular Malaysia = 4.92 mil ha; Sarawak = 6.09 mil ha; Sabah = 3.60 mil ha), 2.04 mil ha of State/Alienated forest, and about 1.83 mil ha of National Park & Wildlife/ Bird sanctuary. From the log production viewpoint, Malaysia has about 13.42 million hectares (11.38 mil ha from PFR and 2.04 mil ha from State/Alienated forest). Malaysia has about 5.06 mil hectares of totally protected forests (3.23 mil ha from PFR and 1.83 mil ha from National Park & Wildlife/ Bird sanctuary). This is summarised in **Figure 6.3**.

Figure 6.2 A typical hill forest in Malaysia

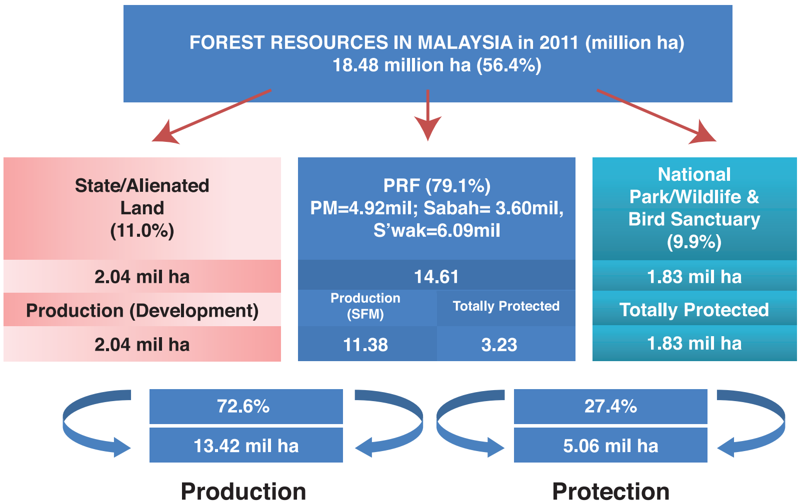



Figure 6.3 Forest resources in Malaysia in 2011

Source: Abd. Rahman Abd Rahim 2012

## 6.11.2 FOREST SUSTAINABILITY BETWEEN PENINSULAR MALAYSIA, SABAH AND SARAWAK

**Peninsular Malaysia**: There is no doubt that the long-term productivity, renewability and sustainability of the forest in Peninsular Malaysia depend mainly on the productive portion of the PFE. It was observed that forests in the East Coast States of Peninsular Malaysia were lightly and selectively logged compared to forests in the West Coast States. The forests in the East Coast States possessed a greater number of residual trees for the next cut, and formed likely areas to be managed on the 30-year cutting cycle (Selective Management System - SMS). Conversely,v  the West Coast forests were logged more intensively leaving behind less trees for the next cut, and became more likely areas to be managed on 55-year cutting cycle (Malayan Uniform System - MUS).

Nonetheless, the general trend in Malaysia is a declining forest area for timber production, i.e. the PFR or PFE. Despite the reduction of forested areas, our policy analyses have indicated a favourable scenario in ensuring the continuous supply of timber from sustainably managed forests. To illustrate, in Peninsular Malaysia, forest management had been practiced to sustain (Wan Razali 2013), as follows:

1. A continuous production of commercial logs from second cycle natural forests managed under MUS/SMS, about:
    - 12 million m$^3$ in 2012 to about 6 million m$^3$ in 2020 (Figure 6.4)
2. A further production of commercial logs from second cycle natural forest managed under MUS until the year 2045 (Figure 6.5)
3. A complementary supply of commercial logs from both plantations of Acacia and rubber, about:
    - 1 to 3 million m$^3$/year from the year 2000 onwards (Acacia)
    - 1.5 to 2 million m$^3$/year from 1994 onwards (Rubberwood)

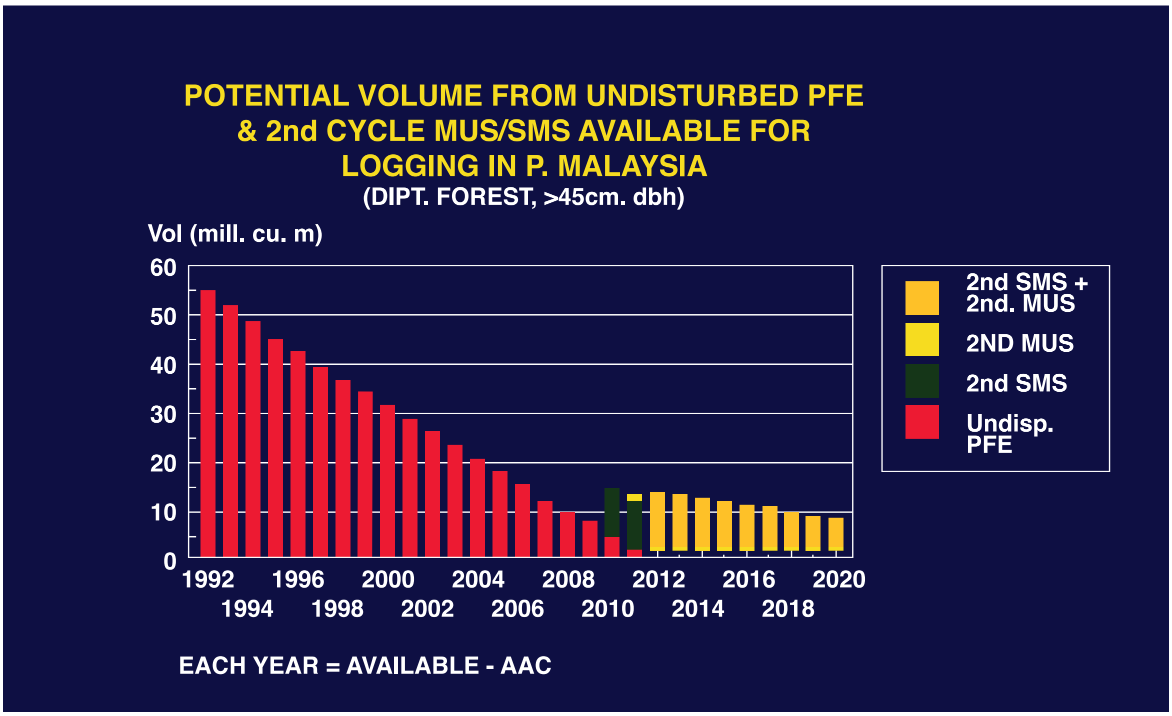



Figure 6.4 Potential volume of undisturbed PFE and second cycle MUS/SMS available for logging in Peninsular Malaysia

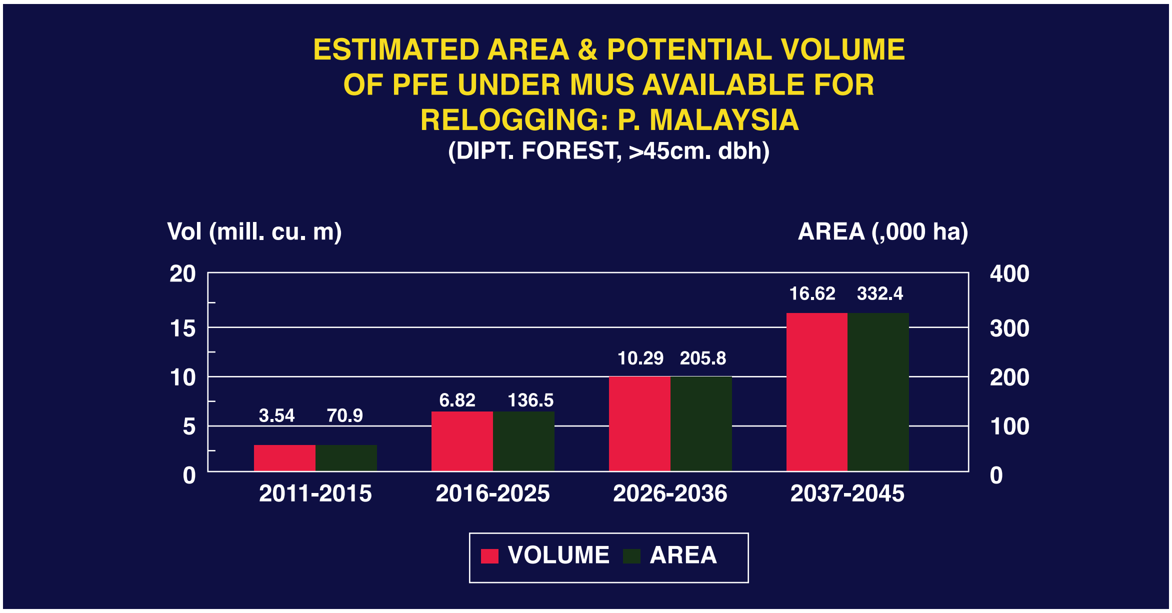



Figure 6.5 Estimated area and potential volume of PFE under MUS available for relogging in Peninsular Malaysia

From **Table 6.3**, the current timber production from the natural forest had more than sustain the domestic consumption until the year 2000. The availability of rubberwood logs and plantation logs is an added bonus to Peninsular Malaysia. However, in the year 2015, the timber production from natural forests alone would not be enough to sustain the domestic consumption, but with the availability of logs from plantation forests and rubber plantations domestic consumption can be created for easily.

The timber processing activities for export demand will have to get logs from elsewhere to keep mills in production. By the year 2015 about 3 million $m^3$ of logs are expected from the plantation forests. This is important as the log supply from natural forest will no longer meet even the domestic consumption. By the year 2020 at least 0.47 million hectares (out of a total of 1.87 mil ha) of logged-over forests within the PFE will be available for re-logging as they were managed under the MUS and were harvested well before 1966. The only question that remains is whether the forest at the end of the cutting cycle will yield the expected volume.

As such, with these arguments, and that the areas logged in 1960s and early 1970s are best managed under MUS, (areas logged in late 1970s and 1980s are best managed under SMS, then Peninsular Malaysia) will have three sources of log supply from its natural forests by the year 2020, from the:

(i) existing remaining natural forests within the PFE;

(ii) regenerated forests, logged and managed under the SMS [note that the forests logged and managed under SMS with 30-year cutting cycle will be reloggable as early as the year 2010]; and

(iii) regenerated forests logged and managed under MUS (about 470,000 ha available by the year 2020).

The natural forests of Peninsular Malaysia are capable of sustained and increased productivity is not seriously in doubt at least from a technical point of view. The 2.85 million ha of forests, out of which 1.30 million ha are to be managed under SMS and 1.55 million ha under MUS, will be able to sustain log production in perpetuity of not less than 3.84 million $m^3$/year, i.e. 2.60 million $m^3$

from the 1.30 million ha and 1.24 million $m^3$ from 1.55 million ha respectively. This management scenario, supplemented by the plantation forests and rubberwood will no doubt give Peninsular Malaysia an advantage or an edge in sustaining its resources, thus ensuring the supply of timber in perpetuity.

*Sabah:* The long term productivity, renewability and sustainability of Sabah's natural forests depend on the PRF's productive portion (Commercial Forest Reserve (CFR)), which is about 2.67 million ha or 36.3% of the total land area. Additionally, the Stateland forests are also available for commercial logging but its production will not be sustained as they have been allocated for other purposes. The timber industry of Sabah is traditionally-oriented to the export of round logs. The typical 'exploit and export' phase of forest development is characterised by a harvest rate in the excess of the productive capacity of the forest; a rate which depends initially on the standing timber in unlogged primary forests. This is evident from the fact that the long-term sustained yield level prescribed for the forests in Sabah is only 2.5 million $m^3$/year (although the long-term sustainable timber production of the CFR, estimated at about 4.5 million $m^3$ will be available by the year 2018 (30-year cycle) when the present CFR would have regenerated and ready for harvest (**Table 6.3**), whereas the timber requirements by the existing industry is about 3 million $m^3$/year. However, the actual production has been steadily on the increase, averaging about 10 million $m^3$ in the last two decades.

Table 6.3 Projected Sustainable Log Production and Domestic Consumption and Export Demand Up to The Year 2015 Compared with 1987 (Million $M^3$ – Roundwood Equivalent)

| Region | Year | Sustainable log supply | | | Domestic consumption[4] | Export demand[5] | | Supply avai. minus domestic consump-tion | Supply avai minus domestic consump-tion& export femand |
|---|---|---|---|---|---|---|---|---|---|
| | | Natural Forest | Plantation Forest | Rubber Planta-tion | | Logs | Processed Products | Surplus (+) Deficit (-) | Surplus (+) Deficit (-) |
| Peninsular Malaysia | 1987 | 8.06 | - | 1.16 | 3.69 | 0.054 | 5.78 | + 5.97 | + 0.14 |
| | 1995 | 4.80 | - | 2.4[1] | 4.29 | 0.020 | 6.98 | + 2.91 | - 4.08 |
| | 2000 | 4.80 | 1.13 | 2.6[1] | 4.66 | 0.020 | 6.98 | + 3.87 | - 3.12 |
| | 2015 | 4.80 | 3.00 | 2.0 | 5.76 | 0.020 | 6.98 | + 4.04 | -2.95 |
| | Perpetuity | 5.70 | 2.30[2] | 2.0 | - | - | - | - | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sabah | 1987 | 11.50 | - | - | 0.35 | 7.50 | 1.98 | + 11.15 | + 1.67 |
| | 1995 | 1.67 | 3.00 | - | 0.41 | 8.50 | 2.85 | + 4.26 | - 7.09 |
| | 2000 | 1.24 | 4.00 | - | 0.44 | 8.50 | 2.85 | + 4.80 | - 6.55 |
| | 2015 | 2.80 | 8.10 | - | 0.55 | 8.50 | 2.85 | + 10.35 | - 1.00 |
| | Perpetuity | 4.50 | 4.68[3] | - | - | - | - | - | |
| Sarawak | 1987 | 13.66 | - | - | 0.41 | 12.64 | 0.18 | + 13.25 | + 0.43 |
| | 1995 | 10.15 | - | - | 0.49 | 10.00 | 0.70 | + 9.66 | - 1.04 |
| | 2000 | 10.15 | - | - | 0.53 | 10.00 | 0.70 | + 9.62 | - 1.08 |
| | 2015 | 7.00 | - | - | 0.65 | 10.00 | 0.70 | + 6.35 | - 4.35 |
| | Perpetuity | 7.54 | - | - | - | - | - | - | |
| MALAYSIA (Total) | 1995 | 16.62 | 3.00 | 2.4 | 5.19 | 18.52 | 10.53 | + 16.83 | - 12.22 |
| | 2000 | 16.19 | 5.13 | 2.6 | 5.63 | 18.52 | 10.53 | + 18.29 | - 10.76 |
| | 2015 | 14.60 | 11.10 | 2.0 | 6.96 | 18.52 | 10.53 | + 20.74 | - 8.31 |
| | Perpetuity | 17.74 | 6.98 | 2.0 | - | - | - | - | - |

Note: [1] (See: FRIM Reports No.49 (1988) – pg. 29: Columns 3 & 5, allowing 10% harvesting loss)

[2] Based on 188,000 ha and rotation period of 15-years for sawlog production with a net volume of 180m$^3$ /ha

[3] Based on 390,000 ha and rotation period of 15-years for sawlog production with a net volume of 180m$^3$ /ha

[4] Domestic consumption based on average per capita wood consumption of 0.27m$^3$ and 2% population increase per year (base year 1987)

= 13.684 million people – Peninsular Malaysia
= 1.305 million people – Sabah
= 1.555 million people – Sarawak

[5] Export demand assumed constant. Processed products include timber, plywood, veneer, and moulding

***Forest Plantations - Future Resource of Sabah**:* The log production from forest plantations of fast-growing exotic is able to supplement the shortfall in the supply of logs from natural forests by 2015. By the year 2015, Sabah is expected to produce about 8 million $m^3$ of plantation log and may fulfil the export quota of about 7.5 million $m^3$/year (Table 6.3). Two questions that remain are whether the market will accept these plantation logs and, if so, at what price. The sustainability of forest resources from Sabah in the year 2015 looks bleak provided that the:

(i) current level of activities within the timber industry is maintained;

(ii) timber from plantations are suitable for the current timber industry; and

(iii) log export target can be reduced in consonance with the sustainable log supply.

Beyond the year 2010, the sustainable management of both of natural forests and plantation forests will definitely be important as to supply the resources in perpetuity of the State of Sabah.

***Sarawak**:* Sarawak is about 69% larger than neighbouring Sabah in terms of its land area. It is to be noted that different sources provide conflicting estimates of the total forested areas, often differing by as much as 1 million hectare. Recent figure (for the year 2011) from Forestry Department, Sarawak indicates that about 8.53 million of its 12.38 million hectares land area are forested (Wan Razali 2013), although an area of about 6.1 million hectares forests is still being quoted (Abd. Rahman 2012).

***Sustained Yield Natural Forest Management: An Achievable Goal for Sarawak?***

As of 31 December 2011, 4.15 million hectares has been designated as Permanent Forest Estate (PFE) for sustainable forest management practices, with the aim of increasing it to 6 million ha; 0.49 million ha for Totally Protected Area (TPA), with the aim of increasing it to 1 million ha; and the remaining areas (3.89 million ha) fall under the category of Stateland forest.

There are, however, a number of important factors which may affect the implementation of sustainable forest management, and hence sustained timber yield, in Sarawak. One of the most important factors is shifting cultivation which is regarded an impediment to such efforts. As logging roads penetrate further into the forests, shifting cultivation spreads beyond the navigable river valleys where it has been traditionally practiced. Areas which have been converted to shifting cultivation will no longer contribute to sustainable management of forest in Sarawak. Short term licenses of 5-10 years duration do not promote sustainable forestry practices either. Furthermore, difficulties in enforcement of rules and regulation due to a lack of infrastructure and accessibility problem in the State, are further constrains to sustainable forest management.

***Future Timber Harvest***: Present and future harvests in both swamp and hill forest come from two sources: (i) virgin or old growth forests and (ii) logged-over forests. Since the 1970s, the current production rate of logs from Sarawak forests is about 8 million $m^3$ per year (WWF 2012). Selective harvesting in the hill forests removes between 6-10 trees/ha. The hill forests produce an average gross volume of 44$m^3$/ha and the swamp forests produce an average gross volume of 62$m^3$/ha. Re-logging operations of the regenerated forests would continue to supply timber on a sustained basis. Inspire of that, this timber is still insufficient to sustain the planned export production of 10 million $m^3$ per year after 1990.

Sarawak will face a critical supply shortage scenario by the year 2015 by about 4.4 million $m^3$ if the annual log export target of 10 million $m^3$ is to be achieved. Although Sarawak can still sustain its local and domestic processing consumptions, by then the planned export production of 10 million $m^3$ per year will have to be revised in accordance with the sustainable timber production of about 7.5 million $m^3$/year. In Sarawak, priority is given to the management of the natural forests for ecological and economic reasons. Plantation forests are only established on areas inside the PFE which have been disturbed by shifting cultivators. A planned target to plant about 2,000 ha/year is unlikely to be achieved and even if achieved, it is too small and too late to have any impact.

The long term annual harvestable increment of Sarawak natural forests is about $2m^3$/ha/year. With only 4.15 million hectares in PFE, of which only 3.77 million hectares are productive, the long term average sustainable timber production would be around 7.5 million $m^3$/year. This considerably less than the present level of log production that has averaged 8 -10 million $m^3$ annually. From the year 2000 to 2015 the productive forests of Sarawak will be able to produce only about 7 million $m^3$ of log/year, gradually increasing to about 7.5 million $m^3$ in perpetuity. This critical stage needs a second look or evaluation by the Sarawak Government, perhaps having to change it export target to that of what the forests can sustain annually (**Table 6.3**).

### 6.11.3 MANGROVES: FORESTS OF THE TIDE

Figure 6.6 Mangroves – Forests of the tide

At the intersection of land and sea, mangrove forests support a wealth of life, from starfish to people, and may be more important to the health of the planet than we ever realised. With one foot on land and one in the sea, these botanical amphibians occupy a zone of desiccating heat, choking mud, and salt levels that would kill an ordinary plant within hours. And yet, the forests mangroves form are among the most productive and biologically complex ecosystems on earth. Throughout the tropical world it is the same: Mangrove forests are the supermarkets, lumberyards, fuel depots, and pharmacies of the coastal poor. Nonetheless, these forests are being destroyed daily. One of the greatest threats to mangrove survival comes from shrimp farming. At first glance, shrimp might seem the perfect export for a poor country in a hot climate. Rich countries have an insatiable appetite for it (shrimp has overtaken tuna to become America's favourite seafood), and the developing world has the available land and right climate to farm it.

Mangroves are also considered as a priceless national treasure from the perspectives of economy, society and environment. The forests provide shelter to the coastal areas and habitat for biodiversity, filter toxic substances and offer opportunities as a source of income for the local communities through marine-based activities such as fishery and aquaculture, and local industries such as charcoal production and poles. Mangrove forests also provide various environmental services, site for research and environmental education, and potential for ecotourism development. This is the scenario equally fit for Malaysia. For example in the State of Johor, agricultural sector including fisheries, animal husbandries and forestry had provided job opportunities for 119,300 people and contributed about RM5,773 million (11.15%) to the economy of the State of Johor at the end of year 2010.

The total mangrove area in Malaysia is estimated to be 575,000 hectares, of which 60% are in Sabah, 23% in Sarawak and the remaining 17% in the Peninsula. Of the total, 85% have been gazetted as forest reserves, wildlife sanctuaries, RAMSAR sites, and as State and national parks. For instance, there are five mangrove-based RAMSAR sites in Malaysia which include Kukup Island, Tanjung Piai, Sungai Pulai, Kuching Wetlands, and Kinabatangan.

Despite that, it is said that mangrove cover in Malaysia has declined by 30% over the past five decades from 800,000 hectares in the 1950s to 575,000 hectares at present (2010s). Mangrove forests in Peninsula, and Sabah and Sarawak are being rapidly cleared due to the pressures from growing populations in coastal areas. The loss of mangrove areas is highest in Perlis, Selangor, Johor, Sarawak, Negeri Sembilan and Penang. Mangrove forest management plans are thus important as guidelines for planning and managing mangrove resources sustainably by taking into consideration the socio-economic aspects, environmental stability, recreation and ecotourism and conservation of biodiversity.

As expected, over 90% of terrestrial biological species in Malaysia occur within natural forests. Nonetheless, the area of lowland dipterocarp forests is now much reduced due to conversion for agriculture. The remaining forests are logged for timber, but yet the largest reservoir of genetic biodiversity variation of the terrestrial flora and fauna in Malaysia are still found within the remaining forests. And, in the aquatic (including marine) ecosystems, coastal mangroves and coral reefs are known to be very rich in species biodiversity. Reportedly, there exist an estimated 4,000 species of marine fishes and 300 species of freshwater fishes in Malaysia. Accordingly, Malaysia has been identified as one of the 25 'biodiversity hotspots' in the world, with a 'biodiversity hotspot' being defined as a habitat that is rich in biodiversity, but which is also facing grave threats to its continued existence.

Furthermore, the loss of mangrove forests could prove catastrophic in ways only now becoming apparent. What role might these forests play in climate change? For more than 25 years Jin Eong Ong, a retired professor of marine and coastal studies in Penang, Malaysia, and his colleagues have been exploring a less obvious mangrove contribution: the carbon budget of mangroves - the balance sheet that compares all the carbon inputs and outputs of the mangrove ecosystem - and they have found that these forests are highly effective carbon sinks. They absorb carbon dioxide, taking carbon out of circulation and reducing the amount of greenhouse gas.

The measurements suggest that mangroves may have the highest net productivity of carbon of any natural ecosystem [about 45 kilograms per 0.4 hectares per day] and that as much as a third of this may be exported in the form of organic compounds to mudflats. Mangroves, it seems, are carbon factories, and their demolition robs the marine environment of a vital element. Conversion of a mangrove forest to a shrimp pond changes a carbon sink into a carbon source, liberating the accumulated carbon back into the atmosphere - but 50 times faster than it was sequestered.

The critical role of the coastal ecosystems including mangroves in maintaining the climate is also being increasingly acknowledged. For instance, the term 'blue carbon' sinks/storage is used to define this further. Out of all the biological carbon (or green carbon) captured globally, over half (55%) is captured by marine living organisms, not on land. Hence, it is called blue carbon. Continuously increasing carbon dioxide ($CO_2$) and other greenhouse gas emissions are contributing to climate change. The mangrove depletion is further exacerbated by rapid economic development in the coastal areas apart from unsustainable forest practices, land conversion/ reclamation for agriculture, aquaculture, mining, industrial, port expansion, urbanisation, tourism, infrastructure development.

*Mangroves and Mudflats:* There generally has been a decline in the mangrove cover for both the total mangrove area (36% decline, 1973-2005: Tan 2007) and the mangrove forest reserves (22% decline, 1980-2005: Tan 2007) in Malaysia. There are approximately 41 true mangrove flora taxa in Malaysia (Tan 2005)& (Tan 2007).

Many mangrove reserves gazetted during the colonial period have since been degazetted and made available for other uses. Added to that, even those mangrove forests that survived the onslaught are being choked by coastal pollution contributed by domestic and industrial wastes. Therefore, we need to find a balance between meeting increasing present-day needs on the one hand, and conserving the environmental support system provided by mangroves, on the other. Of course, there are many options before the Government to achieve such a goal. Given their multiple-use potential, it is imperative that the management of mangrove based terrestrial and aquatic ecosystems be undertaken within the context of integrated coastal area management planning. This would essentially require cooperation and commitment between various agencies and stakeholders to ensure the sustainability of mangrove resources, now and in the future.

The Maritime Institute of Malaysia (MIMA) International Conference on Mangroves a few years back called for a "no-net loss" policy, with the goal to balance the loss caused by economic development through reclamation, mitigation and restoration efforts - so that the total acreage of mangrove areas in the country does not decrease, but remains constant or, preferably, increases. One good example that would relate to this approach would be the Matang Mangrove Forest in Perak. Through an integrated management approach and strong support from the Government, this forest is one of the best managed areas under sustainable forest management system in Malaysia and is also recognised as the best managed mangrove forest in the world.

***Prospects for Mangroves conservation and rehabilitation in Malaysia***: As early as during the 8th Malaysia Plan (2001-2005) period, measures were already taken to intensify the conservation and rehabilitation of mangrove forests, to serve as an effective shoreline defence system against erosion, wave action and tsunamis. This approach of managing the natural resource is being continued in the 9$^{th}$ and 10$^{th}$ Malaysia Plans: (2006-2010) and (2011-2015), respectively, through:

(i) adopting an Integrated Coastal Zone Management Policy to promote the conservation and preservation of marine and coastal resources;

(ii) intensifying the rehabilitation and improvement of coastlines through regeneration and revegetation programmes;

(iii) developing a comprehensive management plan for mangroves and coastal forests to arrest the mangrove depletion rate to ensure a continuous supply of resources as well as to mitigate the impact of coastal erosion and tsunamis; and

(iv) developing a Coastal Vulnerability Index to guide the design of programmes to enhance coastal zone management.

## 6.12 ENVIRONMENTAL CONTRIBUTION OF FORESTS

### 6.12.1 BIOLOGICAL BENEFITS OF FORESTS

At the heart of forest conservation in Malaysia are its protected areas that have been legally gazetted by law. In Malaysia, protected areas cover both terrestrial and marine environments. Almost half of the total land area in Malaysia is protected under Permanent Reserve Forests (PRFs - as of 2011: 14.61 million hectares) of which about 11.38 million hectares and 3.23 million hectares are set aside respectively for sustainable timber production and as totally protected areas for their economic, social, and conservation values.

In addition, the protected area network has been further extended by the designation of national and State parks, wildlife reserves, bird and game sanctuaries, such as Taman Negara, Cameron Highland Wildlife Sanctuary, Tioman Wildlife Reserve, Royal Belum State Park, Tasek Bera (RAMSAR wetland) and Tanjung Piai (RAMSAR mangrove) in Peninsular Malaysia; Gunung Mulu National Park, Lanjak-Entimau Transboundary Conservation Area and Lambir Hills National Park in Sarawak; and Kinabalu Park, Danum Valley and Maliau Conservation Areas in Sabah.

Apart from the legal mechanisms deployed to gazette the protection of forests within the PRFs as defined by the National Forestry Policy 1978 (Revised 1992) and the National Forestry Act 1984 (Amended 1993), Section 10(1) stipulates 11 functional classes for various functions, this includes for biological and environmental benefits such as follows (Shamsudin *et al.*):

(1) Timber Production Forest under sustained yield

(2) Soil Protection Forest

(3) Soil Reclamation Forest

(4) Flood Control Forest

(5) Water Catchment Forest

(6) Forest Sanctuary for Wildlife

(7) Virgin Jungle Reserve

(8) Amenity Forest

(9) Education Forest

(10) Research Forest

(11) Forest for Federal Purposes

At the species level, biological protection comes in the form of 32 timber species not allowed to be harvested within the PRFs in Peninsular Malaysia (MTC 2006), 48 protected plant species in Sarawak under Section 31 of Sarawak Wildlife Protection Ordinance (MTC 2006), and 20 genera/ species of trees listed as 'prohibited species' under Sabah's various enactments (MTC 2006).

## 6.12.2 CONSERVATION MEASURES OF FLORA AND FAUNA BIODIVERSITY

The strong environmental consciousness of recent years has also created certain buzzwords. 'Biodiversity' and "product certifications" are two of them; which are currently debated upon. Malaysia is fully committed to the cause of protection and conservation of its biological resources. Malaysia - one of the twelve "Mega Diversity" countries is rich in biological diversity, as reflected in the figures presented (approximate in number):15,000 Angiosperms (flowering plants), 8,500 species in Peninsular Malaysia, as follows:

- 293 species of mammals;
- 12,000 species of moths;
- 600 species of mosses,
- 1,200 species of birds,
- 449 species of freshwater fish,
- 294 species of reptiles,
- 1,200 species of fern and fern allies,
- 171 species of amphibians,
- 1,200 species of butterflies, and
- > 100,000 species of other invertebrates (insects, worms, etc.).

The twelve countries (China, Brazil, Australia, India, Congo, Mexico, Indonesia, Peru, Colombia, Madagascar, Malaysia, and Ecuador) together contain at least 60% of the world's known species.

Land use changes were extensive in the 1960s to early 1980s, when much of the lowland natural forests and landscapes were converted to plantation agriculture and development. The 70%+ of the land area under natural forest cover shrank to about 63% by 1972 (FAO 1973), further declined to 61% in 1988 to 59% in 1992 to 58% in 1995 and to 57% in 1996 (Anon 2009). The declining trend seemed to stabilise from the year 2000 and by the year 2010 the total land area under natural forest cover remains around 19 million ha, close to the 1994 figure.

Thus, over the period 1970 to 2000, natural forest - the storehouse of biodiversity, was reduced by about 20% in the whole of Malaysia, mainly in conversion to the cash crops, oil palm and rubber. Consequently, scientists estimated that 170 of 8500 flowering plants (2%) are extinct (Sunday Times 15 October 2000). Nevertheless, we have reached a time in our development path where we could be more sensitive to the needs of nature and ensure that any further reduction in the extent of our forested land should only be after the most careful of considerations (Wan Razali 2008).

Furthermore, almost all biodiversity conservation measures for Malaysian natural forests are in the form of habitat conservation, especially via the legally established Protected Areas. These areas comprise National and State Parks, Wildlife Sanctuaries, protected areas within the Permanent Reserved Forests (PRFs) and Marine Parks. Recent initiatives include the Trans-boundary Biodiversity Conservation Areas of Lanjak-Entimau Wildlife Sanctuary in Sarawak and Betung Kerihun National Park in Kalimantan, including Pulong Tau National Park in Sarawak and Kayan Mentarang National Park in Kalimantan.

The Heart of Borneo Initiative, spanning across *ca*. 220,000 km$^2$ in Malaysia, Indonesia and Brunei seeks to re-establish forest connectivity and corridors particularly for protected areas which are fragmented due to forest degradation and land use changes (Chua *et al.* 2010). Many environment related legislations have been enacted to protect the country's environment. The National Parks Act 1980 indirectly protects plant populations through habitat protection. Other legislations that have strong elements to protect flora biodiversity include the National Forestry Policy 1978 (amended 1992), the National Policy on Biological Diversity 1998, the National Agriculture Policy 3 (1998 – 2020), the National Physical Plan (2005 – 2010) and International Trade in Endangered Species Act 2008, to name a few.

The National Physical Plan (NPP), as provided for via the Town and Country Planning Act 1976, aims to prioritise land and natural resources for sustainable development. There are six policies that have direct reference to natural resources and biodiversity assets. The Environmentally Sensitive Areas (ESA) shall be integrated in the planning and management of land use and natural resources. The Central Forest Spine (CFS) that is established to anchor the ESA includes the mountain backbone of Peninsular Malaysia, where biodiversities are found.

Distinctively, the States of Sarawak and Sabah have their own separate biodiversity legislations with regulatory and administrative mechanisms to protect biodiversity conservation. These include their Forest Enactments/ Ordinances and Parks Enactments/ Ordinances, and Sabah Biodiversity Enactment 2000 and Sarawak Biodiversity Regulations 2004.

The following general information (**Figures 6.7A, B** and **C**), which is again self-explanatory, provides a snapshot view of Malaysia's biodiversity of the status: Endemic, Endangered, Critically Endangered, and Vulnerable (Sunday Times 15 October 2000, Saw, LG: pers. comm. 2000; Chua *et al*. 2010).

| No. | Country | NBI |
|---|---|---|
| 1. | Indonesia | 1.000 |
| 2. | Colombia | 0.935 |
| 3. | Mexico | 0.928 |
| 4. | China | 0.893 |
| 5. | Brazil | 0.877 |
| 6. | Ecuador | 0.873 |
| 7. | Australia | 0.853 |
| 8. | Venezuela | 0.850 |
| 9. | Peru | 0.843 |
| 10. | Costa Rica | 0.820 |
| 11. | Madagascar | 0.813 |
| 12. | Malaysia | 0.809 |

Figure 6.7A National Biodiversity Index (NBI) of 12 biologically diverse countries

| No. | Endemism |
|---|---|
| 1. | 26% 0f 2830 tree species in Pen. Malaysia. |
| 2. | 20-40% of 3500 tree species in Sabah & Sarawak |
| 3. | 43% of 212 palm species in Pen. Malaysia |
| 4 | 40% of 290 palm species in Sabah & Sarawak. |

Figure 6.7B Tree/ Palm species endemism

| No. | Threatened Category |
|---|---|
| 1. | **35 taxa ENDANGERED(EN)** of which 10 endemic to Pen. Malaysia |
| 2. | **42 taxa VULNERABLE(V)** of which 6 endemic to Pen. Malaysia |
| 3. | **15 taxa CRITICALLY ENDANGERED(CR)** of which 6 endemic to Pen. Malaysia |
| [Note: Peninsular Malaysia has 155 species (worldwide 500 species) comprising 165 taxa of which 34 taxa are endemic; 90 taxa share their range with Sabah & Sarawak; 41 taxa extend their distribution to Sumatra & Philippines]. | |

Figure 6.7C *Dipterocarps* in Peninsular Malaysia: Number of taxa threatened

### 6.12.3 CARBON CONSERVATION AND SEQUESTRATION IN FORESTRY

Climate change represents a significant issue confronting the global community in recent years. This sentiment was reinforced by the landmark 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) - a legally binding document requiring commitments by industrialised countries to reduce their collective emissions of greenhouse gases (GHG) by 5.2% compared to the year 1990. This is a pressing issue indeed because the roles of tropical forests in climate change are profound. IPCC report estimated that in the last decade, anthropogenic emissions totalled 7.1 ± 1.1GtC/year and emissions from deforestation in the 1990s are estimated at 5.8 $GtCO_2$/year (IPCC 2007). Forests in generalaccount for about 80% of the annual $CO_2$ exchange and can sequester between 1.1 to 1.8 GtC/annum in 50 years, representing 20 -25% of carbon emitted each year by combustion of fossil fuels (Makundi *et al*. 1998). Carbon forestry projects in tropical forests are also among the most cost-effective means of achieving climate change mitigation.

Malaysia ratified the UNFCCC in July 1994, UNCBD June 1994, and KP September 2002. This signifies her commitments in addressing the problems of climate change and biodiversity and sets the stage for further works on the issues. Malaysia's best practices approach to forest management has been able to conserve biological resources and carbon stocks by avoiding the deforestation and forest degradation. Malaysia is a net sink, as reported in the NC2 (NRE 2011- **Table 2.4**). The total carbon stock of Malaysian forests amount to about 92 million tC. The total carbon released due to conversion and forest harvesting activities is 26 million tC. After accounting for emission from land conversion, the amount of carbon sequestration or carbon uptake by forest vegetation was 390 million tC. It is noted that Malaysian forests and other woody biomass contributed to about 4% of the tropical forests sink.

Accordingly, the Prime Minister of Malaysia announced at the Climate Change Conference in December 2009 in Copenhagen, an indicator of a voluntary reduction which amounted to 40% of emission intensity of gross domestic product (GDP) by 2020 compared to the 2005 level. This reduction is also conditional on receiving the transfer of technology and adequate financing from the Annex 1 Parties (industrialised countries), in line with the spirit and aspiration of the UNFCCC. The emission intensity is based on carbon - the indicator used to measure voluntary emission reduction, and is actually the total emission per unit of GDP. The indicator was adopted as it allows emission to grow in tandem with the economic growth, which is crucial for developing nations, like Malaysia. Essentially, 40% reduction of carbon intensity is equivalent to about 10% reduction of GHG emission from business-as-usual.

Therefore, in absolute term, Malaysia has to reduce about 40 million tonnes from the projected total of 376 million tonnes of GHG emission by the year 2020. To achieve the 40% reduction of carbon intensity, three mitigation options have been identified consisting of (i) Renewable Energy (RE), (ii) Energy Efficient (EE), and (iii) Solid Waste Management (SWM). The three areas are projected to contribute 45 million tonnes of

GHG reduction by 2020, provided effective and efficient mitigation measures are implemented. The above scenarios have not factored in the important role of forest as carbon sink. Assuming Malaysia can maintain its current level of forest cover, an additional 250 million tonnes of $CO_2$-equivalent could be sequestered yearly. The objectives for managing forest lands generally include the following:

(i) sustainable forest management;

(ii) industrialwood (and fuel wood) production;

(ii) protection of non-timber natural resources (e.g. biodiversity, water, and soil);

(iv) recreation; and

(v) rehabilitation of damaged ecosystems, etc.

Carbon conservation and sequestration resulting from managing for these objectives will be an added benefit. Forest management practices that meet the objectives given above can be grouped broadly into three categories based on how they are viewed to curb the rate of increase in atmospheric $CO_2$ (Brown 1996), namely (i) Management for Carbon Conservation, (ii) Carbon Sequestration (or Storage), and (iii) Carbon Substitution, as discussed below:

***(i) Management for Carbon Conservation*** - mainly prevents carbon emission by maintaining existing (and increasing) carbon pools in forests as much as possible through controlling deforestation, protecting forests in reserves, controlling anthropogenic disturbances, and changing harvesting regimes. Sustainable management practices, such as extending harvesting cycles, reducing damage and negative impacts to remaining trees and soil respectively (e.g. reduce or low impact logging), and reducing logging waste, ensure that a large fraction of carbon is conserved.

The idea is analogous to "*Compensated Conservation*" when financial incentives are made available through a proposed *"Stabilisation Fund"* (27th SBSTA, Bali 2007). This approach recognises countries with large tracts of forests and low or stabilised deforestation rates that practices sustainable forestry as having reduced emissions from deforestation and thereby contributed to mitigating climate change. Malaysia is in favour of this approach, but will have to address it from various perspectives, especially from future arrangement of REDD+ in reducing emissions.

The national REDD+ strategy is currently under development. Though the main options for REDD+ areknown, it is expected that the national REDD+ strategy will also provide guidance on the following:

- *Goals, Objectives and Scope* – which will also determine the objectives of a finance mechanism (e.g. Malaysia may develop a dedicated REDD+ mechanism or umbrella/ conservation fund),

- *A brief description of the REDD+ institution* and its relationship to government agencies and a list of responsibilities – which will determine the governance principles of a finance mechanism, and

- Adescription of how funds will be managed – the development efforts for a finance mechanism may need to be integrated. Malaysia firmly believes that any carbon saving as a result of early action projects could be used under a future market or other related mechanism (carbon market).

***(ii) Carbon Storage*** - management increases the amount of carbon in vegetation and soil of forest ecosystems and this include the following practices: increasing forests area – natural and plantation, protecting forests from degradation, assisting regeneration – eitherassisted or natural, and extending the lifetime of wood products. Sequestering carbon by storage management is only a short term option -

though the process may take place over a several decades depending on the attainment of maximum carbon density of such forests, producing a finite carbon sequestration potential beyond which little additional carbon can be accumulated.

***(iii) Carbon Substitution*** - involves accelerating the transfer of forest biomass carbon into products such as construction materials and fuel, rather than using fossil-fuel-based energy and products and cement-based products. This approach involves extending the use of forests for wood products and fuels obtained either from establishing new forests or plantations, or increasing the growth of existing forests through silvicultural interventions. Over long time periods (> 50 years), the displacement of fossil fuels either directly, or through production of low-energy-intensive wood products, is likely to be more effective in reducing carbon emissions than physical storage of carbon in forests or forests products.

Malaysia's best practices approach to forest management has been able to conserve biological resources and carbon stocks by avoiding the deforestation and forest degradation. This is illustrated by the fact that the area of Malaysian forest under the PRF has not changed substantially in the last 10 years. A conservative and cautious approach will be adopted to ensure that a clear and fair mechanism is developed that will address the issues dealing with leakage, permanence and additionality that recognises the socio-economic impacts to developing tropical countries with relatively large areas of forests and where forestry is an important economic sector. Reducing emissions from tropical deforestation/ forest degradation can take any of the following three avenues:

- setting aside and protecting forested land with any degree of forest cover;
- ensuring that minimal forest degradation occurs in permanent production forests (no land-use change) through sustainable forestry practices; and
- ensuring deforestation activities (involving a land-use change) carry out with due regard to social and environmental sensitivity and reduces or minimises emissions.

(i) Malaysia can do a lot more as a carbon sink by promoting tree planting in urban areas and underutilised lands outside of the designated forest reserves, and as renewable energy in the form of wood pellets for internal use and export to replace fossil fuels and as horticultural carbon for carbon sequestration.

## 6.13 MALAYSIAN FORESTS ARE PLACES OF ADVENTURE

To raise general awareness and knowledge on the importance of ecotourism in National and State Parks and Amenity Forests [functional classes of PFR under Section 10(1) of the National Forestry Act 1984 (Amended 1993)], there must be sufficient opportunities to allow people to have direct and first-hand experiences on the wonders of forests and their economic, ecological, spiritual, cultural and aesthetic importance. Such experiences must be planned to endear the public to nature, thereby promoting healthy quality of life.

The rise in park tourism and outdoor adventure sports is testament to the greater recreational use of forests. National and State Parks continue to improve facilities and programmes to cater to foreign and local interests. The popularity of mountain biking, rock-climbing, rafting and kayaking and other special uses demands additional recreational and better management to avoid environmental conflicts. The concept of forest-stay or "forest-camping", akin to the present "home-stay" program in lieu of city hotel accommodation, has a great potential in park tourism. There are a number of forest recreation areas operated by State Forestry Departments that buffer the flood of urban and rural outdoor enthusiasts to lessen the overall impacts of tourism. **Appendix 5** lists National and State Parks and number of Amenity Forests in Malaysia.

## 6.14 PAYMENT FOR ENVIRONMENTAL SERVICES

Payment for Environmental Services (PES) is a mechanism to allow the provision of indirect ecosystem services in which those provide environmental services (the provider) should be compensated for doing so and those who receive these services (the users) should pay for their provision. In the year 2006, the New Sunday Times published a statement from the then Minister of Natural Resources and Environment, Malaysia to states:

"*Focus on tourism, not timber: We cannot wait forever and continue to earn from logging. For how long do they want to depend on it? ... hoped that the States would come up with proposals on how they planned to reduce logging before phasing it out altogether...".* (Though possible for implementation – in the context of present constitution/ legislations and legal framework, etc., it will be a long way before PES can be fully implemented in Malaysia (EPU 2012)).

**What is PES good for?** Forests provide a multitude of tangible goods and environmental services. Timber is the most obvious tangible due to its potentially detrimental environmental and social impacts when not properly managed. Services include regulation of ecological cycles such as water, carbon/ carbon dioxide, protection of climate and soil resources, conservation of biological diversity, provision of eco-tourism and recreation services, as well as provision of cultural, spiritual and social services. In Malaysia there seems to indicate PES activities are being implemented to a limited scale in biodiversity conservation, watershed protection, carbon sequestration, and landscape/ seascape beauty (EPU 2012).

**What are the real problems in the valuation of environmental services?** Many studies on economic valuation of natural resources and ecosystem services were carried out by many researchers at the universities, research institutions, government departments and agencies, and NGOs. Nevertheless, the applications of these results for effective implementation of PES are still limited, for which R&D efforts – in the areas of benefit cost analysis, compensation/ natural resource assessment, valuing alternative land use option, priority setting for conservation and management of natural resources and environment, and national income account, must be given serious attention. Economic valuations of marine and agriculture ecosystems are not as advanced as terrestrial or forest ecosystem, the former of which need to be strengthened and enhanced. Nonetheless, Appendix 6 shows the extent of monetary values associated with the payments for environmental services (Awang Noor).

## 6.15 MAJOR FORCES TO DRIVE FOREST TRANSITION

See **Appendix 7**.

## 6.16 SCIENCE, TECHNOLOGY AND INNOVATION: REFLECTIONS AND POLICY RECOMMENDATIONS

| **Science, Technology and Innovation on Land & Forests** | **Development of STI Opportunities** | | |
|---|---|---|---|
| | 2013-2020<br>(Short term) | 2021-2035<br>(Medium term) | 2036-2050<br>(Long term) |
| **STI#1. Wood Consumption and Sustainable Timber Production:**<br><br>Sustainable production of second and subsequent growth natural forest is from 17-18 million $m^3$/year; the actual average production was around 28 million $m^3$/year. | A reduced availability commensurate with the level of sustainable log production from the natural forests: 20 million $m^3$/year.<br><br>Put the system of PES in place to complement and supplement the incomes derived from the forests. | A reduced availability commensurate with the level of sustainable log production from the natural forests: 17 - 18 million $m^3$/year. | A reduced availability commensurate with the level of sustainable log production from the natural forests: 17 - 18 million $m^3$/year. |
| **STI#2. Review Government Policies on AAC & Maximum Extractable Volume:**<br><br>AAC is more than what the forests can sustainably yield. Breakeven (RM) net harvest volume (under SMS) = 21$m^3$/ha. National averaged volume logged= 62-85 $m^3$/ha. The windfall profit is already obvious under present practices. | Reduce AAC<br><br>Practice sustainable and improved logging techniques, e.g. reduced impact logging, low impact logging, etc. | Limit the logged volume to about 40-50$m^3$/ha net via strict volume control mechanism. | " |
| STI#3. Maintaining and Improving Mega-Diversity Status:<br><br>Currently Malaysia is at 12th position with NBI=0.809. NBI < 0.800 will disqualify a country from being listed as a Mega-Diverse country. | Maintain the NBI | Maintain the NBI | Maintain the NBI |

| **Science, Technology and Innovation on Land & Forests** | **Development of STI Opportunities** | | |
|---|---|---|---|
| | 2013-2020<br>(Short term) | 2021-2035<br>(Medium term) | 2036-2050<br>(Long term) |
| **STI#4. Ensuring and Allocating Sufficient Government Incomes Derived from Harvesting of Timbers to Finance Increasing Costs of Reforestation, Afforestation, and Other Practices of Sustainable Forestry**:<br><br>Current trend of financial investment ploughed back into forests development is minimal, averaging less than 1% of GDP | Investment ploughs back into the forest development = 1% of GDP<br><br>Practice intensive natural forest management or grow resources via industrial plantations. | Investment ploughs back into the forest development = 1.5% of GDP | Investment ploughs back into the forest development = 2.0% of GDP |
| **STI#5. Ensuring "Equitable Green Price" For Certified Timber and its Products:**<br><br>Current certified timber and timber products obtain a green price premium of only between 3-10% over the uncertified timbers.<br><br>Proposing or leading a timber organisation to control and manage an ***equitable tropical timber pricing*** internationally – just like what OPEC does to manage or influence petroleum price. | | " | " |
| STI#6. Production Efficiency and Productivity & Product Diversification:<br><br>Generally, production efficiency in the timber sector in Malaysia is low. Sawmills and plywood mills achieved a recovery rate of less than 60%; Harvesting losses are estimated to be as high as 50% of the commercial tree volume in Malaysia. Traditional markets have to be supplemented with new markets; Forestry was a sunset industry. | The outdated machinery must be upgraded or replaced.<br><br>Mill wastes must be converted to more effective use and high value products.<br><br>Manufacturing recovery increases between 60-70%.<br><br>Harvesting losses reduce to less than 40% | Manufacturing<br><br>recovery increases between 70-80% and harvesting losses reduce to less than 30%.<br><br>Timber manufacturers need to obtain up-to-date market information on designs and consumers preference, focusing on quality and cost-saving manufacturing. New and improved products developed. | Manufacturing<br><br>recovery increases beyond 80% and harvesting losses reduce to less than 20%.<br><br>Forestry becomes an industry of environmental and socio-economic importance. |

| Science, Technology and Innovation on Land & Forests | Development of STI Opportunities | | |
|---|---|---|---|
| | 2013-2020 (Short term) | 2021-2035 (Medium term) | 2036-2050 (Long term) |
| **STI#7. Increasing Business Opportunities via Quality and Environmental Management Systems:**<br><br>Regulatory, market and public interest in corporate environmental performance is growing, as can be seen by the increasing media coverage of issues such as climate change, product legislation, recycling, publication of company environmental report, certification and SFM. | Companies to lower their risk and enhance their image, market share and competitive position by implementing a proactive quality and environmental management strategies, e.g. ISO 9001 QMS & ISO 14001 EMS. | " | " |
| **STI#8. Increasing Cost of Production & Pressure on Forest Product Companies:**<br><br>Malaysia's economy is experiencing the perils of a developed economy in the form of labour scarcity and higher costs; has to compete with other countries in every aspect of its forestry and manufacturing activities leading to a low price advantage of products manufactured in those countries.<br><br>Companies are highly vulnerable to environmental issues because they depend almost entirely on forests as natural resources for inputs. | Provide companies practicing sustainable forest management and sustainable products manufacturing with tax incentives involving land, technologies acquired or developed, and R&D | `` (ditto mark) | `` (ditto mark) |

## 6.17 CONCLUSION AND WAY FORWARD

The future development of land and forests has to be integrated and synchronized with other changing external environments, vis-à-vis water, energy, waste, and carbon and climate. The need to ensure that forestry sector will continue to be the responsibility of both the Federal and State Governments is beyond any doubts in order to bring about the socio-economic development to the States and nation and the highest quality of life of its people. Concerns over the future of forests transcend national boundaries and forests are going to be extremely important. A way forward at this juncture when dealing with forests in the context of environment is to ask a basic question:

What can public and private decision makers learn from a wide-ranging look at the social sciences and the issues of human choice and environment (e.g. land and forests, water, energy, waste and carbon and climate) that illuminates the evaluation of policy goals, implementation strategies, and choices about the path forward? At the present moment, most proposed policies, roles, strategic directions and action plans have focused on the development and implementation of inter-governmental agreements on immediate emission reduction, sustainable forestry, biodiversity, and other environmental issues. In the spirit of cognitive and analytical pluralism, Malaysia should also look beyond the present policy priorities to see if there should be adjustments and changes, either partially or wholly, by considering the following suggestions for public and private decision making by policy makers:

i) view the issue of land and forests with respect to water, energy, waste, and climate change holistically, not just as the problem of emission reduction;

ii) prepare for the likelihood that social, economic, and technological change would be more rapid and have a greater direct impact on human population than climate change and biodiversity conservation;

iii) incorporate land and forests with respect to water, energy, waste, and carbon and climate, and biodiversity concerns into other immediate issues, such as employment, defence, economic development, and public health; and

iv) direct resources into identifying vulnerability and promoting resilience, especially where the impact would be the largest.

# CHAPTER 7
# SCIENCE, TECHNOLOGY AND INNOVATION FOR THE ENVIRONMENT

## 7.1 INNOVATION OPPORTUNITIES AND MODELS

Environmental issues offer numerous opportunities for science, technology and innovation. A list of research and innovation possibilities is compiled at the end of this chapter for ease of reference. This list is based on what is reasonable and logical. However, the nature of innovation is such that progress based on what is reasonable and logical would normally be in small increments. Small incremental advances can add up to make big advances. In spite of that, the biggest advances are often the unexpected ones, as they are unexpected, and have revolutionary consequences. Such revolutionary breakthroughs are the result of unconventional thinking 'out of the box', and doing what conventional wisdom would regard as foolish. We obviously cannot provide a list of foolish things to do or even encourage anyone to do anything foolish.

Unconventional ideas have to be worked on quietly by innovators in their own time and at their own expense until they have sufficient proof of concept to convince others, especially venture capitalists, to support them. Hence, the personal motivation of innovators has to be exceptionally high. Added to that, different societies have difference tolerance levels for unconventional ideas and personalities, and this may contribute to the different levels of innovation observed for different countries and reflected in the international indices for innovation.

The market for innovation is global – making the competition to innovate also global. There is an obvious link between innovation and economic development. In any listing of innovation by countries, the most economically advanced countries are also the countries in which the most innovations originate. Not with standing, many countries have tried to promote innovation, using Silicon Valley as their model, with hardly any having come close to the impact of Silicon Valley in their ability to attract innovators. To illustrate, Japan had set up an ultra-modern Science City in Tsukuba. Other countries, including Malaysia, have set up Technology Parks. Many universities have set up incubation centres in their campus grounds. These efforts have been mostly infrastructure-driven and sooner or later, they settle down into a conventional property-management mode. The technology firms that move in would, if successful in their business models, put down roots and pay rents for continuing to occupy their premises. On their part, the property owners find it easier to be landlords than to deal with cash-strapped innovators. As a result, such artificially-created Silicon Valleys do not attract the innovators that they were originally meant to attract. It has been noted that budding innovators in Silicon Valley typically live cheaply, work long hours, socialise with other innovators and can hardly afford to pay rent.

Promising new kinds of innovation hubs or 'ecosystems' in the IT world have now come into existence in many cities and some are described in *The Economist* of January 18.2014. Location-wise, the one closest to Malaysia is Block 71, a seven-storey building in Ayer Rajah Crescent, Singapore, that had been slated for demolition. It is now home to over 100 start-up companies that develop software. Software companies are relatively easy to start up because software development does not require expensive infrastructure.

For IT hardware innovation, Shenzhen in Southern China has become the world's busiest hub for reasons that are peculiar to Shenzhen. Most of the world's digital devices are manufactured and assembled in Shenzhen. All the components that go into digital devices are available here;any as open-source components unencumbered by intellectual property rules. These components can be used as building blocks in innumerable ways to create all kinds of new architectures, like LEGO building blocks that can be assembled in innumerable ways. There are whole shopping malls in Shenzhen dedicated to components from screws and cables of all kinds to circuit boards, chips, LEDS, and more advanced components. There are service providers who can fabricate anything to order, cheaply and quickly. As a result Shenzhen has attracted hardware innovators from all over the world.

The closest to an IT hub in Malaysia is Low Yat Plaza in Bukit Bintang, Kuala Lumpur, but this is a retail hub, not an innovation hub. However, Low Yat Plaza has knowledgeable people in the repair business who could be innovators given the right conditions. With the right kind of encouragement it might develop into an IT innovation hub.

In agriculture, Cameron Highlands has become a very active innovation hub. Here are thousands of farmers growing all kinds of crops, from vegetables to fruits and flowers, for export and for local consumption. Every available bit of land is used, under open sky as well as in green houses that allow fine control of light and watering regimes. Suppliers of agrichemical and agricultural equipment and chemicals are concentrated here. The older generation of lowly-educated but innovative farmers is being replaced by college graduates who are no less innovative. The conversation in the coffee shops is about farming. This is the kind of social atmosphere that characterises an innovation hub.

The lesson to be learnt is that innovators create their own communities in places where the social and physical conditions are right for them. Innovators have a synergistic effect on each other and attract each other. They need critical mass of numbers to attract the kinds of service providers that they need. The Government can help by recognising innovation hubs no matter what form they take and providing supporting infrastructural services such as roads, electricity and water, but to a large extent an innovation hub is a community that regulates itself. External attempts at regulation could be counter-productive.

Independent innovators can thrive in IT and agriculture without institutional support because the cost of testing ideas and coming up with proofs of concept is not high. In environmental matters covering climate change, water, energy, waste and forest management, institutional support would be necessary because of the need for expensive equipment, land and man-power for relatively long periods of time. Nonetheless, the institutions that have been set up for research have a number of deep-seated problems that need to be recognised and addressed.

One issue is that most existing institutes in Malaysia have no special mandate for research on environmental issues. This shortcoming can be rectified by allowing all of them to expand or reinterpret their mandates to cover environmental research. Most of the existing research institutes have staff of different disciplines, e.g. biology, chemistry, physics and engineering, which can form interdisciplinary teams for environmental research, and most research institutes already have the basic laboratory equipment for many kinds of analytical work.

The second issue is much more difficult to deal with. Social scientists have found that institutions develop distinctive institutional cultures and it is very difficult to change an established institutional culture. Malaysia's research institutions were not designed and managed as innovation hubs. Hence, knowledge of how manage an innovation hub is lacking. Managers are promoted by seniority. Furthermore, research is done with no sense of urgency. Competition in research has been eliminated on the grounds that duplication is wasteful and research efforts should not be duplicated. Hence, due to lack of competition there is no comparative data on performance, No scientist has ever been reprimanded or terminated for being unproductive.

In Life Sciences such as agriculture and forestry, the outmoded colonial model of institutional research is still predominant, half a century after independence. Scientists in Sarawak work on Sarawak issues, those in Sabah work on Sabah issues and those in Peninsular Malaysia work on Peninsula issues. In any international conference in the life sciences, Malaysian scientists tend to be ranked below 'international' scientists from USA, Japan, Europe, Australia, and now Singapore because they lack a world view. All of our research institutions are used to hosting visiting scientists from overseas, but the Malaysian funding system does not allow Malaysian scientists to work in neighbouring countries as visiting scientists to strengthen their expertise. In developed countries an expert is expected to be driven by ambition to be a global expert. In developing countries, the ambition to become local expert is already considered a great ambition.

The third problem is the absence of a DIY (do it yourself) culture. Great emphasis is placed on paper qualifications. Good innovators without the paper qualifications do not get adequate recognition. Technicians who are good at repairing, and modifying equipment are not recognised and rewarded for their skills. In all scientifically advanced countries scientific innovation includes the modification and design of equipment. Malaysia imports nearly all of its scientific equipment. Such equipment is often not optimal for a tropical humid environment and break down easily.

The technicians who repair the equipment should get to know what the weaknesses are and if encouraged to do so, could innovate improved versions. Such technicians and their scientific bosses should be constantly tinkering with equipment. Instead there is such a fear of equipment breakdown in Malaysia that sensitive equipment are locked up and guarded jealously until they become out of date or inoperable. This became obvious during the *nipah* virus epidemic, when researchers trying to locate electron microscopes found that most of the electron microscopes in Malaysia were safely locked up and unserviceable. In scientifically advanced countries, the equipment is fully utilised, repaired and used again around the clock. The technicians get better and better at maintaining equipment and improving them. A new and improved model then appears on the market. The 'protective' users of equipment have to keep buying new versions and never learn the secrets of equipment innovation.

The universities could be centres of research and innovation and some of them have been specially designated as research universities. University scientists have considerable freedom to do research, and inspirational professors are in a position to gather post-graduates around themselves to form research hubs. Nevertheless, the focus in universities is to produce new knowledge in publishable form, which is not the same as to producing innovations that can be implemented in practice. And, for that matter, universities alone cannot provide sufficient impetus for innovation.

## 7.2 RANKING OF INNOVATION

### 7.2.1 THE RANKING OF COUNTRIES BY THE BLOOMBERG INNOVATION INDEX

The level of innovation in a country is widely perceived to offers a good measure of national strength in innovation. The Bloomberg Index of 2014 (www.bloomberg.com/slideshow/2014-01-22/30-most-innovative-countries.html) provides a ranking of 215 countries using seven weighted factors and the most recently available data.

The 30 most innovative countries are as follows, with South Korea ranked as the most innovative:

- South Korea
- Sweden
- United States
- Japan
- Germany
- Denmark
- Singapore
- Switzerland
- Finland
- Taiwan
- Canada
- France
- Australia
- Norway
- Netherlands
- United Kingdom
- Austria
- Russia
- Belgium
- New Zealand
- Luxembourg
- Italy
- Czech Republic
- Poland
- China
- Hungary
- Hong Kong
- Ireland
- Portugal
- Israel

### 7.2.2 FACTORS OF EVALUATION

The factors used in evaluation and their weightings are as follows:

***R&D intensity (20%)*:** Research and development expenditure as a percentage of gross domestic product.

***Productivity (20%)*:** GDP per employed person age 15 and over.

***High-tech density (20%)*:** The number of high-tech public companies – such as aerospace and defence, biotechnology, hardware, software, semiconductors, Internet software and services, and renewable energy companies – as a percentage of all publicly listed companies.

***Researcher concentration (20%)*:** The number of professionals, including Ph.D. students, engaged in R&D per one million people.

***Manufacturing capability (10%)*:** Manufacturing value added as a percentage of GDP and as a share of world total manufacturing value added.

***Tertiary efficiency (5%)*:** The number of secondary graduates enrolled in post-secondary institutions as a percentage of cohort; the percentage of the labour force with tertiary degrees; annual science and engineering graduates as a percentage of the labour force and as a percentage of total tertiary graduates.

***Patent activity (5%):*** Resident patent filings per one million residents and per $1 million of R&D spent; patents granted as a percentage of the world total.

(Sources: Bloomberg, International Monetary Fund, World Bank, Organisation for Economic Co-operation and Development, United Nations Educational, Scientific and Cultural Organisation, U.S. Patent and Trademark Office, World Intellectual Property Organisation).

## 7.3 SUPPORT FOR INDEPENDENT INNOVATORS

It is difficult to be an independent innovator. Apart from having to support themselves through the innovation phase they face tough problems in the commercialisation phase. Patenting is also a double-edged sword. Patents are time-consuming and expensive to obtain. Innovators not only need to be aggressive in defending their patents but may also face legal challenges themselves over alleged patent infringements. Big organisations have a big advantage over small independent innovators in the aggressive use of the patenting system.

To promote independent innovation in the IT world, business schools have emerged which provide innovators with advice, training and mentoring and providing a forum in which innovators can make their presentations to interested parties and potential venture capital investors. The accelerators are run as businesses and charge a fee for a course that typically runs for three months.The volume of innovation has probably not reached a sufficient level in Malaysia to create a demand for such business schools or 'accelerators/ as they prefer to be called.

Another model to promote innovation is being tried in Oxford University, which is not a conventional university but an amalgamation of autonomous colleges. One of the best known of these colleges is Wolfson College which is a college catering solely to graduate students pursuing Masters and Doctoral degrees. It opened in 1969 and has now produced thousands of MSc and DPhil graduates (an Oxford PhD is designated as DPhil). This year, it started a programme called Wolfson Innovate in which all Wolfson members and fellows are invited to make presentations about their creative ideas. They have to submit written outlines from which a selection will be chosen for oral presentation before an audience and a panel of judges. Winners will be awarded cash prizes of up to £5000.

Indeed, this model is one that ASM could adopt as an experiment to try out on its fellows and associates. In contrast, a salaried scientist paid RM3K per month costs RM36K per annum to support and may not produce any worthwhile innovation. This amount of prize money paid for an innovation that has a good chance of taking off could be a much better deal.

## 7.4 LIST OF OPPORTUNITIES FOR RESEARCH, DEVELOPMENT AND INNOVATION

This is a list of opportunities extracted from the various chapters in this study. It is not an exhaustive list, there are many more ideas may be extracted by rereading the relevant chapters.

***Carbon and Climate***

- Replacement of coal by wood for generation of electricity:
- Adaptation of coal-burning plants to wood-burning for generation of electricity;
- Development of accelerated systems for growing wood for fuel, including plant breeding, crop rotation and soil management;
- Develop more efficient ways to grow trees on waste land, road sides and parks;
- Develop more efficient harvesting and post-harvest processing technologies for a wood-pellet industry;
- Improving the design of new buildings and modification of old buildings to reduce cost of air conditioning;
- Improving the energy-efficiency of machines and manufacturing processes; and
- R&D to develop a biochar or horticultural carbon industry for carbon sequestration and soil improvement.

*Water*

- Water supply and demand:
- R&D on availability, potential and management of groundwater sources.
- Technology to detect and fix water leakage in distribution systems.
- Development of rainwater harvesting technologies.
- Water pollution control:
- R&D on non-point source pollution control
- R&D to support revision of existing pollution control standards
- Development of automated monitoring instruments and networks
- Research on effects of novel and new pollutants
- Advanced water and wastewater treatment systems:
- New water treatment technologies
- New sewage treatment technologies
- Water and green growth:
- Development of water sensitive designs

*Energy*

- R&D on treatment and fermentation of agricultural biomass
- R&D on integrated system for biogas recovery and microalgae cultivation
- R&D on integrated solid waste management approach
- R&D on waste treatment and clean manufacturing technology for solar cells and panels
- Development of high capacity and cost-effective energy storage technologies
- R&D on thorium-based nuclear power
- R&D on cogeneration and trigeneration of power and heating and cooling duties

*Waste*

- Innovation of accelerated composting technologies in accordance with local climatic and biotic conditions
- Research on ways to promote separation, collection and recycling of waste
- Research and innovation for use of biomass waste for the generation of methane for energy
- Research and innovation for composting of chicken dung

*Land and Forests*

- Research to increase the productivity of second, third and subsequent generation forests.
- Research for effective management of forests for biodiversity, scenic conservation and outdoor recreation / tourism.
- Research to determine economic harvest level of natural forests under different scenarios and research on PES.
- Research on reducing harvest loss, increasing manufacturing recovery and innovating new product designs

# APPENDICES

# APPENDICES

## Chapter 4

## APPENDIX 1

### Potential of microalgae

The potential of microalgae cultivation for biofuels production can be seen in Table A1 in the Appendix.

Culturing microalgae (with high or low lipid content) requires the least land area compared to other oil crops such as soybean, sunflower, rapeseed, and oil palm in meeting the European Union (EU) biofuels target in year 2010. In addition, microalgal biofuels obviate the sustainability concern arising from the food versus fuel issue due to use of edible oils to produce biofuels (Lam & Lee 2011).

Table A1. Comparison of Oil Yield for Various Oil Bearing Plants and Microalgae

| Oil crop | Average oil yield (ton/ha/year) | Area to meet EU biofueldemand in 2010 (million ha)[a] | Share of Malaysian agricultural land area (%)[b] |
|---|---|---|---|
| Soybean | 0.4 | 25.0 | 379 |
| Sunflower | 0.46 | 21.7 | 329 |
| Rapeseed | 0.68 | 14.7 | 223 |
| Oil palm | 3.62 | 2.8 | 42 |
| Jatropha | 4.13 | 2.4 | 37 |
| Microalgae with high lipid content | 126 | 0.1 | 1 |
| Microalgae with low lipid content | 54 | 0.2 | 3 |

Notes:

[a] EU biofuel target in year 2010 is equivalent to 10 million ton.

[b] Total agricultural land area in Malaysia is equivalent to 6.6 million ha.

Chapter 5

## APPENDIX 1

### Planning incentives for better waste management in Malaysia

1. Prevention of generation of waste; reduction of volume of waste, introduction of 'separation' of waste in cities into the following:

    A. Household waste (for composting)

    B. Glass: to be recycled.

    C. Plastics: to be recycled

    D. Metals: to be recycled

    E. Paper: to be recycled

    D. Others including woods: to be burned to produce energy

2. Increase of landfill tax for disposal by 10%

3. Increase of landfill tax by 50% for disposal of organic waste such as food

4. Provide incentives for Palm Oil Mills to eliminate their landfills filled with EFB, Ash, Shells, mesocarp fibres, POME etc.

5. All landfills and chicken dung composting plants and other anaerobic facilities which produce odour have to be forced to install bio filters

6. Initiate recycling of E-wastes

7. Implement official policy to recycle Palm Oil Mill wastes using zero waste composting systems like in Indonesia.

## APPENDIX 2

### Role of Composting Councils

Composting councils are a necessary tool of governments to promote government's environment policy to the people and to promote and bring all 'green' ideas from the people of the world to the governments. Composting Council activities can create new jobs with the development of new composting industry.

Many countries recognise the need to coordinate composting activities at national and regional level. There are many composting councils which are situated all over the world. They include:

- US Composting Council
- Canada Composting Council
- European Composting Network
- Darwin City Council
- Washington Organic Recycling Council
- Composting Council of Oregon
- North Carolina Composting Council
- Recycling Council of Alberta
- Pennsylvania Resource Council
- Recycling Council of Ontario
- Bristol City Council
- Composting Garden Waste Council
- Leister City Council: composting competition, Belfast City Council: waste collection
- Manchester City Council: should we compost, Dunedin City Council, West Sussex County Council, Ceredigion County Council, Norwich City Council, Wire Borough Council, Coventry City Council, Bassetlaw District Council, Davenport City Council, South Oxfordshire On line Council, Ipswich City Council, The Guardshille Council, Detroit Council, Renwick City Council, Christchurch City Council, Compost Advisory Council etc.

The main activities of Composting Council in rich plant biomass countries such as Malaysia should be as following:

- to support and strengthen government ecological policy;
- to develop standards for production of high quality composts and to control quality of composts in the Malaysian markets;
- to review and assess the applied composting technologies in Malaysia to produce a high quality compost as a waste management practice;
- to conduct inspections on all composting plants related to the hygienic norms and future development of compost standards;
- to increase the number of working places in the emerging new composting industry in Malaysia;
- to promote strong environmental ethics, an entrepreneurial spirit and demonstrate that environmental protection and economic development come and work together in the composting industry and support good business practices;
- to organise and coordinate composting of all wastes of government mills and to support and coordinate CDM Projects. At present, the largest amount of income from CDM Projects are going mainly to foreign holdings and less to private companies in Malaysia;
- to influence people to make, buy and use compost thus creating a demand that leads to a larger commercial market and expand commercial scale composting and mulching businesses;
- to provide policy to protect the environment from pollution: soils, waters, air and biodiversity;
- to promote more efficient utilisation of plant biomass which is in large amount in Malaysia but percentage of effective utilisation is small;
- to minimise erosion rate, increase soil bioremediation and reduce the number of landfills in Malaysia;
- to develop new composting technologies to use degraded and accumulated biomass in landfills of Malaysia;
- to support farm scale composting, home composting, composting of food and green wastes and to coordinate introduction and development of organic agriculture in Malaysia;
- to promote and support expansion of the compost market;
- to organise public support of all kinds of composting and utilisation of all kinds of organic wastes for composting;
- to organise conferences, discussions, exhibitions, compost trade shows and workshops;
- to coordinate research on the relationship: composting-soil-air-biodiversity-plant yield;
- to support customer confidence in compost selection and utilisation;
- to coordinate government and non-profit organisations in education and training of a young generation for composting of wastes;
- to promote business contacts between composting people;
- to develop certification programmes and organise Assurance programmes;
- to promote recognition of compost application as the best method to adapt present agriculture to negative influence of climate change and reduce the strength and number of such negative factors as heat waves, worm nights, intense droughts, flooding's, competition of weeds and expansion of pathogens and insect pest ranges; and
- to participate in Global Recycling Network.

Chapter 6

## APPENDIX 1

### The National Forestry Policy 1978 (Revised 1992) in Brief

Malaysia has yet to adopt a truly National Forestry Policy (NFP) which covers the whole country. Nevertheless, a National Forest Policy for Peninsular Malaysia was approved by the National Forestry Council (NFC) and endorsed by the National Land Council (NLC) in 1978. The NFP has been adopted by all the States in Peninsular Malaysia and is supported by Sabah and Sarawak which have forestry policies with similar objectives.

The objectives of this policy are being strictly adhered to by the State authorities and the NFC is kept informed of all forestry development activities implemented in the various States. The National Forestry Policy ensures uniformity in the implementation of all forest management, conservation and development strategies towards achieving common objectives. The objectives of the National Forestry Policy are as follows (National Land Council 1978):

- To dedicate as Permanent Forest Estate sufficient areas of land strategically located throughout the country in accordance with the concept of rational land use in order to ensure:
- Sound climatic and physical conditions of the country, the safeguarding of water supplies, soil fertility and environmental quality and the minimisation of damage by flood sand erosion to river sand agricultural lands, such forest land being known as 'protective forests';
- The supply in perpetuity at reasonable rates of all forms of forest produce which can be economically produced within the country and are required for agricultural, domestic and industrial purposes, such lands being known as 'productive forests';and
- The conservation of adequate forest areas for recreation, education, research and the protection of the country's unique flora and fauna, such forest lands being known as 'amenity forests'.

- To manage the Permanent Forest Estate with the objective of maximising social, economic and environmental benefits for the Nation and its people in accordance with the principles of sound forest management;
- To pursue a sound programme of forest development through regeneration and rehabilitation operations in accordance with approved silvicultural practices in order to achieve maximum productivity from the Permanent Forest Estate;
- To ensure thorough and efficient utilisation of forest resources on land not included in the Permanent Forest Estate, prior to the alienation of such land, by means of proper coordinated planning by land development agencies in order to obtain maximum benefits for the people through complete harvesting and processing of such resources, adhering strictly to the optimum need of local processing industries;
- To promote efficient harvesting and utilisation of all forms of forest produce and to stimulate the development of appropriate wood-based industries with determined capacities commensurate with the resource flow in order to achieve maximum resource utilisation, create employment opportunities and earn foreign exchange;
- To ensure the sound development of trade and commerce in and to promote the exportation of forest products;
- To promote effective Bumiputra participation in the forest and wood-based industries consistent with government policy;
- To undertake and support an intensive research program in forest development aimed at achieving maximum yield from the Permanent Forest

Estate, maximum direct and indirect benefits from harvesting and utilisation and, above all, maximum financial return on investment in forest development activities;

- To undertake and support a comprehensive program of forestry training at all levels in the public sector in order to ensure an adequate supply of trained manpower to meet the requirements of forestry and wood-based industries;

- To encourage private sector involvement in forestry research and training at all levels with a view to accelerate industrial development and enhance the quality of professionalism in forestry and forest industrial practices;

- To foster, by education and publicity, a better understanding among the community of the multiple values of forests to them and their descendants; and

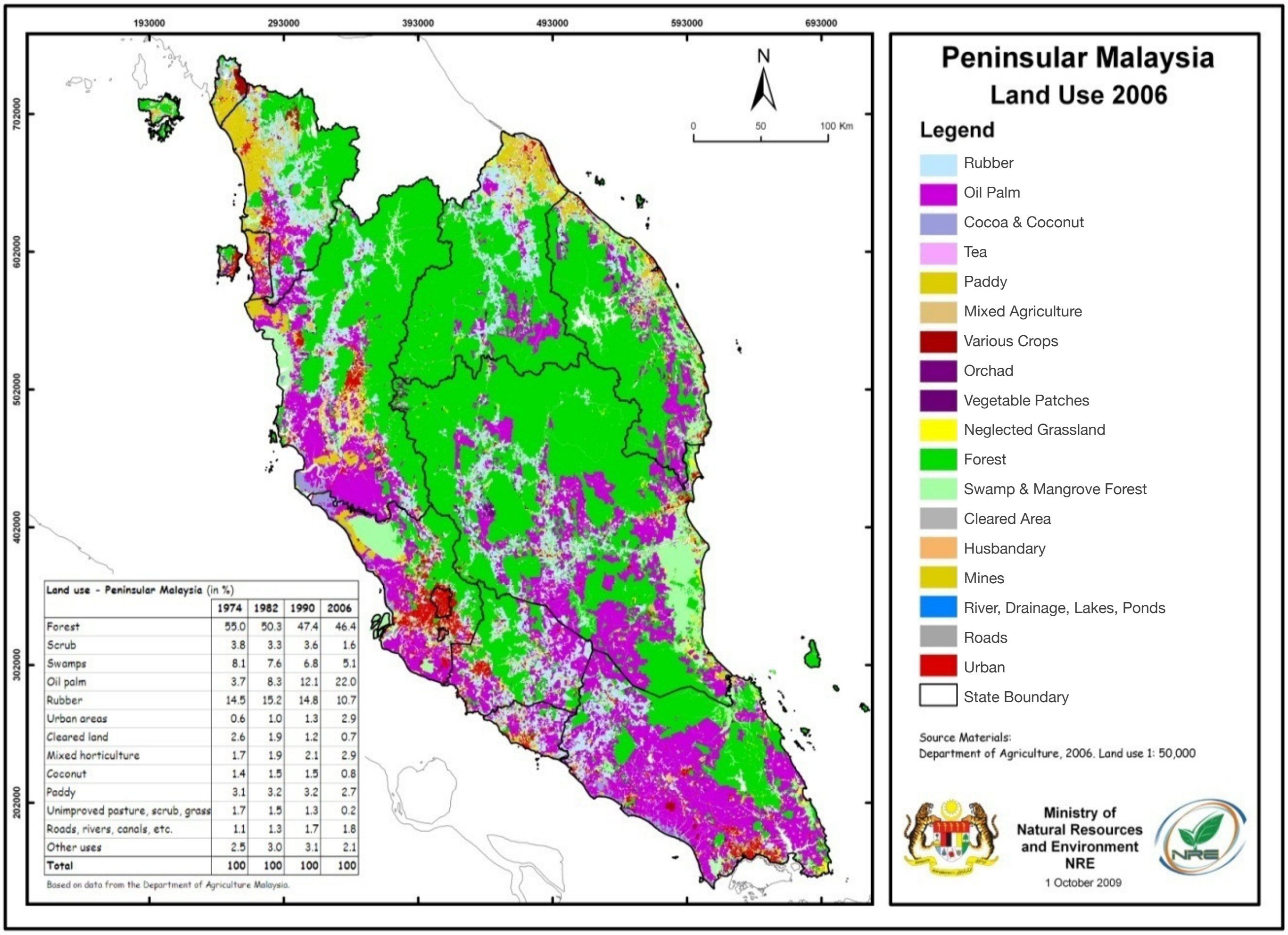
- To foster close co-operation among all in order to achieve optimum utilisation of the valuable natural resources of the country.

The Forest Policy of Sarawak, approved by the Governor-in-Council in 1954, remained the basis for forestry practices in that State (Government of Sarawak 1954). Similarly, the State Forestry Policy of Sabah serves as a guideline for the sustainable management of the forests; for planning and implementation of Forestry Department activities; and for promotion of awareness of the values of forests (Sabah Forestry Department 1989)

The National Forestry Policy 1978 (Revised in 1992) contains many salient features involving 'permanent forest estate' (with protection, production, amenity, and research and education functions); regeneration and rehabilitation operations; development of appropriate forest industries; production of non-wood forest produce; conservation of biological diversity and areas with unique species of flora and fauna; establishment of forest plantation by private sectors; intensive research programs in forestry and forest products; comprehensive program of forestry training at all levels for the public and private sectors; education in forestry and undertake publicity and extension services; and comprehensive program in community forestry to cater for the needs of the rural and urban communities.

## APPENDIX 2

### A Typical Land Use Pattern in Peninsular Malaysia




Land use - Peninsular Malaysia (in %)

| | 1974 | 1982 | 1990 | 2006 |
|---|---|---|---|---|
| Forest | 55.0 | 50.3 | 47.4 | 46.4 |
| Scrub | 3.8 | 3.3 | 3.6 | 1.6 |
| Swamps | 8.1 | 7.6 | 6.8 | 5.1 |
| Oil palm | 3.7 | 8.3 | 12.1 | 22.0 |
| Rubber | 14.5 | 15.2 | 14.8 | 10.7 |
| Urban areas | 0.6 | 1.0 | 1.3 | 2.9 |
| Cleared land | 2.6 | 1.9 | 1.2 | 0.7 |
| Mixed horticulture | 1.7 | 1.9 | 2.1 | 2.9 |
| Coconut | 1.4 | 1.5 | 1.5 | 0.8 |
| Paddy | 3.1 | 3.2 | 3.2 | 2.7 |
| Unimproved pasture, scrub, grass | 1.7 | 1.5 | 1.3 | 0.2 |
| Roads, rivers, canals, etc. | 1.1 | 1.3 | 1.7 | 1.8 |
| Other uses | 2.5 | 3.0 | 3.1 | 2.1 |
| Total | 100 | 100 | 100 | 100 |

Based on data from the Department of Agriculture Malaysia.

## APPENDIX 3

### Definition of Forests

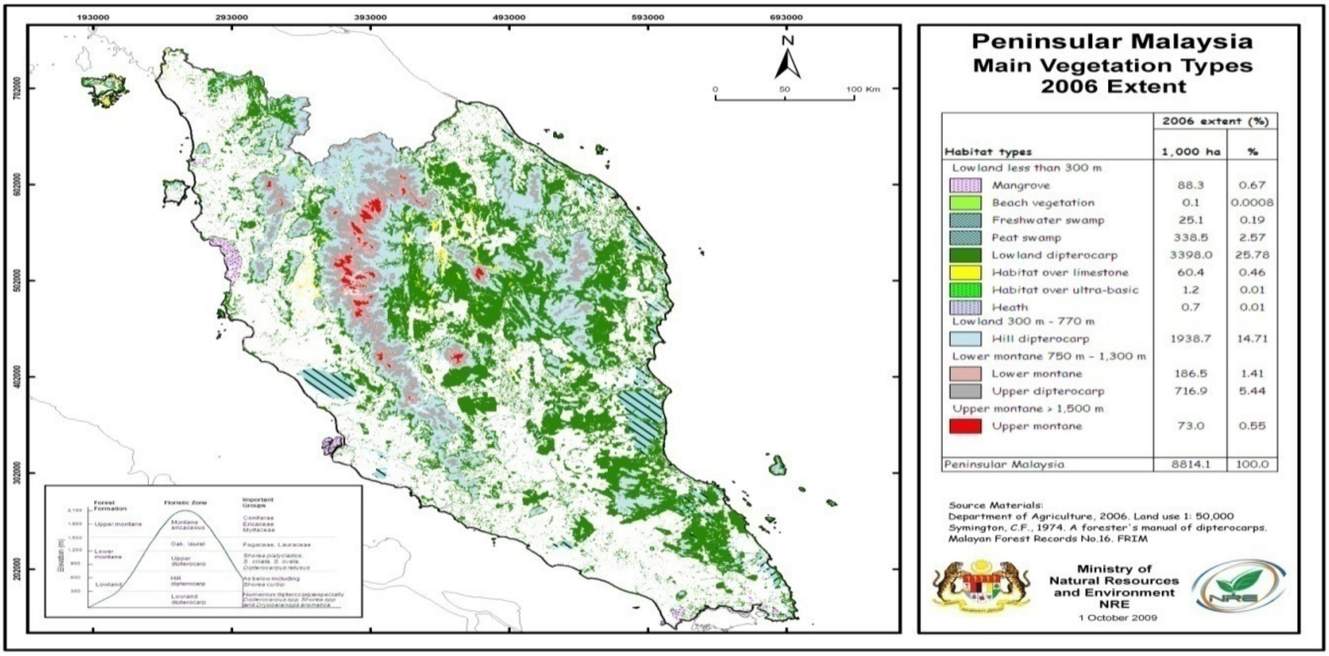
Malaysia uses the current FAO definitions of various land cover classes, e.g. total area, forest, other wooded land and other land as defined below:

| Land cover class | Definition |
|---|---|
| Total area1 | Total area (of country), including area under inland water bodies, but excluding offshore territorial waters. |
| Forest | Land with tree crown cover (or equivalent stocking level) of more than 10% and area of more than 0.5 hectares (ha). The trees should be able to reach a minimum height of 5 meters (m) at maturity in situ. May consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground; or open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10%. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10% or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest.<br><br>Includes: forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and width of more than 20 m; plantations primarily used for forestry purposes, including rubberwood plantations and cork oak stands.<br><br>Excludes: Land predominantly used for agricultural practices |
| Other wooded land | Land either with a crown cover (or equivalent stocking level) of 5-10% of trees able to reach a height of 5 m at maturity in situ; or a crown cover (or equivalent stocking level) of more than 10% of trees not able to reach a height of 5 m at maturity in situ (e.g. dwarf or stunted trees); or with shrub or bush cover of more than 10%. |
| Other land | Land not classified as forest or other wooded land as defined above. Includes agricultural land, meadows and pastures, built-on areas, barren land, etc. |
| Inland water | Area occupied by major rivers, lakes and reservoirs. |

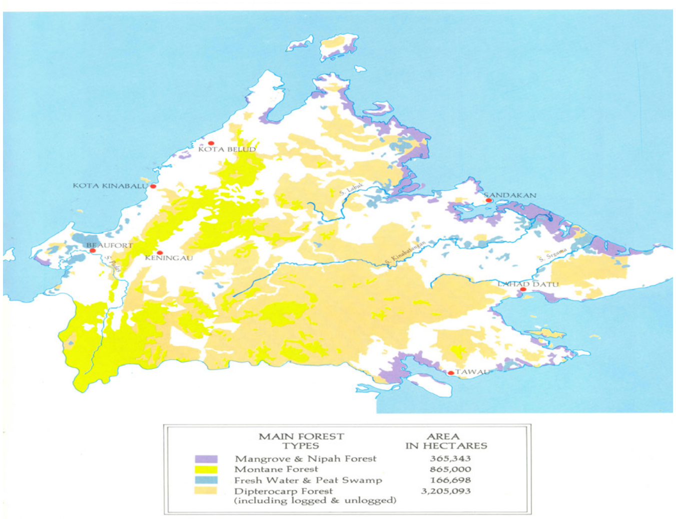
[1)] The Total Land Area is defined as the Total Area, but excluding Inland water.

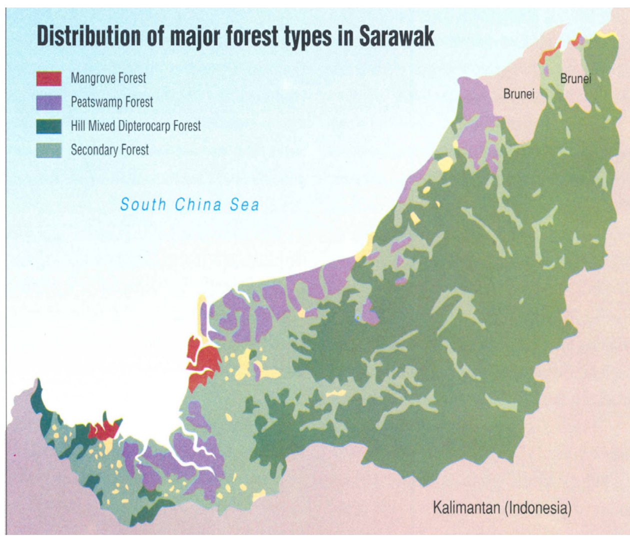
## APPENDIX 4

### Main Vegetation/ Forest Types in Peninsular Malaysia, Sabah and Sarawak




MAIN FOREST TYPES IN SABAH



## APPENDIX 5

### National Parks in Malaysia

| 1. | Peninsular Malaysia | Forest Area (ha) |
|---|---|---|
| | Taman Negara (Pahang, Kelantan and Terengganu) | 434,340 |
| 2. | **Sabah** | |
| | Kinabalu Park | 75,370 |
| | Tunku Abdul Rahman Park | 1,289 (+ 3640 ha Coral Reef) |
| | Pulau Penyu Park | 15 (+ 1725 ha Coral Reef) |
| | Pulau Tiga Park | 607 (+ 15,257 ha Coral Reef) |
| | Bukit Tawau Park | 27,972 |
| | Crocker Range National Park | 139,919 |
| 3. | **Sarawak** | |
| | Bako National Park | 2,728 |
| | Niah National Park | 3,139 |
| | Gunung Mulu National Park | 52,866 |
| | Lambir Hills National Park | 6,950 |
| | Similajau National Park | 7,064 |
| | Gunung Gading National Park | 5,430 |

### Number of Amenity Forests and State Park Forests in Peninsular Malaysia

| No. | State | No. of Amenity Forest | No. of State Park Forest |
|---|---|---|---|
| 1 | Johore | 8 | - |
| 2 | Kedah | 27 | - |
| 3 | Kelantan | 3 | 1 |
| 4 | Melaka | 4 | 1 |
| 5 | Negeri Sembilan | 11 | - |
| 6 | Pahang | 28 | 1 |
| 7 | Perak | 16 | - |
| 8 | Perlis | 3 | 1 |
| 9 | Pulau Pinang | 2 | 1 |
| 10 | Selangor | 10 | 1* |
| 11 | Terengganu | 11 | - |
| 12 | Kuala Lumpur FT | 1 | - |

*All Amenity Forests are located inside the State Park Forest, known as Taman Warisan Negeri Selangor

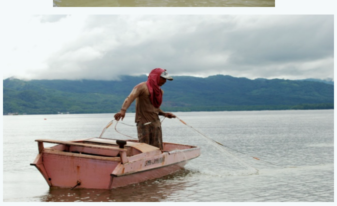
## APPENDIX 6

### Payments for Environmental Services (PES)

| Total Economic Value (TEV) of some Forest Goods and Services in the North Selangor Peat Swamp Forest (Net Present Value at 8% discount rate) | | | |
|---|---|---|---|
| **No** | **Good/Service** | **NPV at 8% (RM million)** | **Note** |
| 1 | Timber | 321.21 | 26.649 ha are commercial forrests |
| 2 | Hydrological | 109.56 | Iriigation water accounted for 99% of the hydro-logical value |
| 3 | Carbon:<br>Above ground<br>Below ground | <br>583.33<br>99.03 | A value of RM14 per Ct was used |
| 4 | Ecotourism | 1.78 | WTP of RM1.42 per peson used |
| 5 | Fish | 2.08 | Based on fishing in Sg. Tengi and main canal. |
| 6 | Asam Kelubi | 0.023 | Based on socio-economic survey by Lim *et al.* (1998) |
| 7 | Total social value | 113.437 (10%) | Item 2+4+5+6 |
| 8 | Total global value | 682.36 (61%) | Item 3 |
| 9 | Total private value | 321.21 (29%) | Item 1 |
| **Grand Total** | | **1,117.01** | |

Source: AG Awang Noor

## Economic values of mangroves along Peninsular Malaysia (GEF/UNDP/IMO, 1999)



| **Use values** | | **Gross value (RM)** |
|---|---|---|
| **Use values** | | **2,475,741,981** |
| **Direct use:** | **market value** | **233,721,896** |
| *Charcoal and poles* | | 91,365,205 |
| *Fish & prawn* | | 16,266,907 |
| *Mud crabs* | | 13,476,857 |
| *Tourism* | | 112,612,927 |
| **Indirect use:** | **Non-market value** | **2,238,036,135** |
| *Nursery role* | | 1,094,871,841 |
| *Carbon sequestration* | | 480,729,717 |
| *Protection from erosion* | | 662,434,577 |
| **Option value:** | | **3,983,950** |
| Biodiversity value | | 3,983,950 |
| **Non-use values** | | **2,932,185,680** |
| Existence value | | 2,932,185,680 |
| **Use and Non-use values** | | **5,407,927,661** |
| Nonmarket value (96%) >> market value (4%) | | |

Source: AG Awang Noor

## APPENDIX 7

### Major Forces to Drive Forest Transition

### 1. Drivers to Deforestation and Forest Degradation

According to Abdul Rahim and Mohd Shahwahid (2009), the forested land in Malaysia is slowly giving way to agriculture especially oil palm and other forms of land use to support the growth in its population, foreign exchange earnings and Gross Domestic Product (GDP). This creates a conflict between agriculture production, forest management and the country's economic development. Hence, in the context of Malaysian deforestation, the implication is that agricultural expansion especially the oil palm, total GDP, population and also export of timber products could be the main factors that influence forest loss.

### 1.1 Commercial Logging

Commercial logging is one of the proximate causes of deforestation (Geist &Lambin, 2001)3. This process of creaming or removing selected trees amidst dense vegetation on rather delicate soil causes much more damage than actual number of trees or the volume of timber taken out would suggest. It was found that the logging operations in Indonesia destroyed about 40% of the trees left behind (Debjani 2012)4.

In East Kalimantan, the seat of Indonesia's lucrative timber trade logging firms are required to leave behind 25 select crop trees per hectare. However, in practice there is no logger who would leave the required number of younger trees, and the notion that the woodland shall be ready for another valuable timber harvest in forty years appears to be the best wishful thinking (Debjani 2012).

The above picture on commercial logging has failed to acknowledge that timber harvestings are being undertaken from two types of forest. The first are from natural forests, mainly located in the low areas whose land and soil are suitable for agricultural, settlement and urban lands. The second are from productive forest reserves where selective harvesting is employed.

The large destructions reported in many of the studies refer to harvesting on forest intended for conversion to other land uses. It can be argued that conceptually selective harvesting of timber in productive forest reserves, in itself is not to be blamed. It is the implementation in various tropical regions that is in question. The practice of cutting down larger trees based on selected species and leaving behind younger ones which can grow into fresh stock to be harvested later may appear rational. In theory, such patch should become ready for harvest back within thirty to forty years. This has been the case in Peninsular Malaysian productive forest reserve, where previous cycles of harvesting have allowed subsequent cycles of harvesting (Wan Razali 1990).

### 1.2 Agriculture Expansion

In numerous developing countries, rural poverty, skewed land ownership and population growth were major influences of deforestation. In Peninsular Malaysia, the development of export-oriented crops plantation such as rubber, that started early in the 20th century, and latter oil palm were directly related to the reduction in forest cover. Sabah followed suit with the same pattern of agricultural expansion and deforestation in the latter part of the 20th century.

In Sarawak, logging has been identified as the primary agent of deforestation, followed by shifting cultivation (Repetto 1988). Nevertheless, the shifting agriculture was the primary agent which caused 50% of deforestation, with logging and smallholder cultivation playing lesser roles (Brookfield *et al.* 1990; Collins *et al.* 1991; Repetto 1988). It can be concluded that heavy logging can cause major forest disturbance. Much damage from logging results from the small clearings in the forest and others.

Thus, it is anticipated that rapid and widespread agricultural expansion will cause a serious threat to natural ecosystems around the world (Tilman *et al.* 2001). Oil palm has become one of the most rapidly grown crops in the world. The global extent of oil palm cultivation increased from 3.6 million ha in 1961 to 13.2 million ha in 2006 (FAO 2007). In 2007, oil palm was grown in 43 countries with a total cultivated area accounting for almost one-tenth of the world's permanent croplands (FAO 2007). The two largest oil palm producing countries, Indonesia (4.1 million ha) and Malaysia (3.6 million ha), are located in Southeast Asia, together contributing 58.3% of global cultivated areas. Coincidentally, this region also consists 11% of the world's remaining tropical forests (Iremonger *et al.* 1997), and harbours numerous endemic or rare species, many of which are restricted to forest habitats (Sodhi *et al.* 2004; Koh & Wilcove 2007). Therefore, the potential impacts of further oil palm expansion on tropical forests and biodiversity in the region are a major conservation concern (Koh & Wilcove 2007).

Although, it has generally been acknowledged that oil palm plantations in Malaysia and Indonesia have been created from existing agricultural lands (e.g. rubber) and forests, the relative contributions of these two land uses to oil palm expansion have to be investigated. Over the period of 1990 to 2005, the Malaysian oil palm grew by a total of 1,874,000 ha (FAO 2007). In a research conducted,it was found that during the period 1990-2005, between 55% and 59% of oil palm expansion in Malaysia was due to forest conversion, and between 41% and 45% of oil palm expansion was likely due to the conversion from pre-existing agricultural lands (including rubber plantations) (Koh & Wilcove 2008).

However, even though Malaysia reported no loss of primary forests during that period (FAO 2006), a large area of secondary or plantation forests were likely to have been converted to oil palm plantations. This finding has strongly proven that oil palm plantation establishments have led to the conversion of either the primary forests or secondary forests. Throughout the developing world, the cultivated land area is expected to increase over 47% by 2050, with about 66% of the new land coming from deforestation and wetland conversion (Fischer & Heilig 1997).

### *2 Key Points Leading to Afforestation and Reforestation – Forest Plantation Programme & Special Purpose Vehicle (SPV)*

From 1981 to 1995, the government embarked on a major plantation programme known as the Compensatory Forest Plantation Programme (CFPP) which envisaged to establish about 188,000 hectares of forest plantations in Peninsular Malaysia (Johari 1988). The Asian Development Bank (ADB) had financed USD24.5million to establish about 40,000 hectares of forest plantations in Peninsular Malaysia for the period from 1985 to 1989 (Phase I). By the end of 1989, only 35,152 hectares had been planted (JPSM 1992).

Similarly, the World Bank had financed the establishment of about 150,000 hectares of forest plantations in Sabah by the year 2000 and by the end of 1988 about 40,000 were planted. During Phase II (1989-1993) of the program, another 42,000 hectares were planned to be planted with *Acacia mangium* at an estimated cost of USD69 million and the Malaysian Government financed USD39.5 million and the remaining USD29.5 million came from ADB loan. The CFPP came to a complete moratorium in February 1992 due to heart rot problem in *Acacia mangium* already planted. By then about 47,066 hectares had been established with a cost of about USD29. 15million (JPSM 1992). Subsequently, the Government decided that the forest plantation program would continue but more species are to be allowed, including the indigenous forest species.

In general, forest plantations did not grow as rapidly as anticipated. Private sector investment in forest plantation was hampered by the long gestation period, the high initial cost of production, high accumulated interest charges and scarcity of large contiguous land for forest plantation. The Malaysian government intervened in the interest of the wood-based industry by establishing a Special Purpose Vehicle (SPV) company to provide financial loans to interested private forest plantation venture named Forest Plantation Development Sdn. Bhd. In March 2005, the Government pursued an aggressive programme to develop forest plantations in Malaysia. Under this National Timber Industry Policy – NATIP, the Government planned to develop 375,000 ha of forest plantation at an annual planting rate of 25,000 ha per year for the next 15 years. Once successfully implemented, every 25,000 ha of land planted is expected to produce 5 million $m^3$ of timber every year based on the wood production of 200$m^3$ per hectare per year (FRIM 2005). A *Special Purpose Vehicle* (SPV) was established to manage the disbursement of *soft loans* (total RM1.045 billion), to carry out auditing process of the plantation as well as to provide technical support and training for the programme. To attract and encourage the private sector (local and foreign companies) to participate in the forest plantation programme, the Government is providing them with *fiscal incentives* such as an investment tax allowance. Besides tax exemptions, the Government also extends soft loans to eligible companies (MTIB 2012). At the same time, various States in Peninsular Malaysia,Sabah and Sarawak offer additional incentives. Eight species are given preference in this program, namely: *Heveabrasiliences, Acacia hybrid, Khayaivorensis/ senegalensis, Tectonagrandis, Azadirachtaexcelas, Noelamarckiacadamba, Paraserianthesfalcataria,* and *Octomelessumatrana.*

In Peninsular Malaysia, lands eligible under SPV must be State lands or alienated lands and not on Permanent Reserved Forests (PRFs). In Sarawak, eligibility is only on areas with License for Planted Forest (LPF) while in Sabah, only areas approved as zone for Industrial Tree Plantation (ITP) under the Sustainable Forest Management License Agreement (SFMLA) is eligible. To date, a total of 62,000 hectares of plantation forest has been established out of the 101,000 hectares approved under this SPV.

Nonetheless, recently, the following forest plantations had been established, including those established under the CFPP and the MTIB's SPV – see Thrust 2 Table (Existing forest plantations by State):

**THRUST 2: Supply of Raw Materials**

**Existing Forest Plantation by State:**

| No | STATE | ACREAGE (ha) | Species |
|---|---|---|---|
| 1 | Johor | 17,407 | *Acacia mangium* and Getah |
| 2 | Kedah | 3.100 | Acacia mangium,Teak, Getah and Sentang |
| 3 | Kelantan | 4,400 | Acacia mangium, Jati Getah, Sentang and etc |
| 4 | Melaka | 113 | Getah, Merawan sp, Karas dan Sentang |
| 5 | Negeri Sembilan | 364 | Acacia mangium, Getah and Karas |
| 6 | Pahang | 19,01/ | Acacia mangium, Getah Sentang and etc |
| 7 | Perak | 1,1/5 | Acacia mangium, Sentang and etcn |
| 8 | Perlis | 6/1 | Teak dan Karas |
| 9 | Selangor | 11,381 | Pine, Getah, Sentang, Mahogany and etc |
| 10 | Terengganu | 3,915 | Acacia mangium, Getah, Kapur and etc |
| 11 | Sabah | 107,441.39<br><br>188,505.65 | Acacia mangium, *A. Crassicarpa, A. Aulococarpa, A. Hybrid, Falcataria moluccana*<br><br>*Eucalyptus grandis, Eucalyptus deglupta, Eucalyptus spp.* and *Gmelina arborea* |
| **TOTAL ACRAGE** | | **581,825.04** | |

Source: JPSM, JPS, JHS and NRE

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**Chapter 7**

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