FINAL REPORT

PLASTICS AND COMPOSITES SECTOR

"Smart Technologies for Smart Industries targeted for Smart Applications for Smart Communities"

MOSTI
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Academy of Sciences Malaysia
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Mega Science 3.0

Draft Final Report Framework Structure

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1.0 INTRODUCTION

1.1 Background

Changes in global networks and societies are now being driven by global megatrends. The plastics and composites industries have seen the emergence of some important trends that can have immense potential. These trends have led to the new market growths throughout the value chain and have initiated unprecedented industry shifts.

Composites and plastics are lightweight materials that have vital enabling growth roles applicable in several industries like automotive, building & construction, electrical, and packaging. As of now, 57.9% of wastes coming from plastics and composites are recovered and 24.1% of the wastes is recycled and converted into new products. In Europe, this is equivalent to about 6.0MT per year. Globally, recycling plastics has turned into a profitable business that utilises about 8.3 million tonnes of plastics for recovering energy.

Majority of human daily activities take advantage of the versatility of plastics and composites to be more convenient and affordable. For example, food packaging only uses about 40% of the plastics currently being produced. Plastics help to lessen food waste, preserve food, and lower the packaging weight. Compared to other materials, plastics' energy efficiency is unrivalled.

Through the years, the plastics industry of Malaysia has gone from manufacturing low-end consumer products that are used for import-substitutions to manufacturers for the export-oriented sector and other high-end industrial applications. The Malaysian Plastics Manufactures Association (MPMA) has stated that in recent years, the share of exports against sales turnover rose from approximately 40% in the late 1990s to about 60%. Some of the examples for composites are:

i. Relevancy to the global trend
ii. Active participation of stake-holders:
    - Value chains: Upstream, midstream and downstream activities
    - how petrochemicals support plastics and composites industry
    - additives (incl. fibres) producers and suppliers
    - Manufacturers: Plastics and composites converters

- End-users – local markets (2015: 30M; 43M population will it be sizable by 2050?) and foreign markets
- Researchers and innovators
- Policy makers
- Funding agencies

iii. Sustainability of plastics and composites
- Ability or adaptability to various regulatory frameworks
- Environmental regulations –increased fuel efficiency and reduced emission
- End of life vehicle
- LCA savings in water, energy, carbon footprint, waste disposal and management of the circular economy (wealth out of wastes WOW; W2W)

iv. Plastics and composites will help in making tomorrow's sustainable future a reality. Plastics and composites will *to innovate* in order for them to become the future material in numerous applications.
- Strategies will be developed in order to manage the challenges that affect the plastics and composite industry. Innovation increases their ability to change their position in the value chain and increase their competitiveness
- To address the global challenges and develop into a world class player, the plastics and composite industry of Malaysia will need to turn its focus on advanced materials, new product development, advanced technology and upgraded skills.

As it goes into the future, the industry needs to bank on these success factors and ensure continued success by enforcing a government structure and building an R, D & C roadmap to help develop its resilience.

1.2 Literature Review

Surveying the vast trove of information in the internet, there appears to be very few foresight studies that have been undertaken specifically for the Plastics and Composites Industry. Most foresight studies tend to look at the overall technology requirements of the nations in the coming decades. There are exceptions. In 2007, Canada has come up with its Technology Road Map for the Canadian Plastics Industry. Among the recommendations is the establishment of "The Polymer Materials Industry Centre for Excellence" with the mission to initiate research and experiment with industrial processes for the polymer materials industry. The focus area identified, among others, include rapid prototyping systems with polymer composites, R&D on adopting structural building materials made from new polymer composite materials and promoting the concept of life cycle analysis (LCA) as a common measure of sustainability.

In the UK, in about the same year, the National Composites Network of UK undertook a Foresight study for the UK Composite industry to identify long term needs in terms of advancement of the technology to enhance competitiveness. The desire was to enhance the nation's composite capability to compete against competitions on the basis of a superior technology base. The reports focus the following generic sectors of the composite industry: defence and aerospace, rail, automotive, process plant, construction and marine.

In 2014, the German Federation of Reinforced Plastics issued the Global and European Composites Market Report highlighting the market developments, trends, challenges and opportunities for the Composite industry. In the coming years, the carbon composites industry is expected to experience continuous growth of about 10%, with its stability being guaranteed by the wind turbines and sport/leisure sectors, aerospace & defence sectors, and, to a certain extent, by the construction and automotive industry. Among the challenges that have to be addressed will be cost-cutting, automation, and the development of manufacturing processes that are appropriate for mass production while supporting important ecological aspects.

In 2008, Thailand developed the Bio Plastic roadmap under the purview of The National Innovation Agency (NIA). The expectation was that by pushing into the Bio Plastic, the strategy will not only develop the plastic industry, but also help other downstream industries grow, particularly the food industry that need plastic items for packaging.

In the national arena, in 2009, A roadmap was developed by the Malaysian Plastics Manufacturers Association (MPMA) based on the inputs given by the participants from the plastics industry. The goal of this roadmap is to help transform the plastics industry into something that can compete at a world-class level. Similarly, it will serve as a guide for plastic processors in meeting the requirements of the government's New Economic Model (NEM). This economic model emphasises the importance of developing a quality workforce through increased industry-driven training and programs that upgrade skills, focusing on innovative processes and radical technologies applicable for high value-added goods, and lessening the industry's dependency on foreign labour.

The same initiatives for composites have been undertaken by some government agencies thus far. The development of the industry is guided by the National Industry

Development Plan, the National Aerospace Blueprint (1997) and the 3rd Industrial Master Plan (2006-2020). It is therefore timely for a foresight to be carried out to study the industry's needs for the next 35 years.

1.3 Benchmarking

The benchmarking exercise helps the industry look outside the country and examine how the other nations were able to achieve their performance levels while understanding the processes that they have applied. Applying the lessons gained from a benchmarking exercise appropriately helps improve one's performance in critical functions.

In the benchmarking exercises, the current best practices and foresight studies of Plastics & Composites in various developed nations will be analysed, particularly those in the EU & USA. Comparison to Asian countries such as China, Korea and Japan and ASEAN will also be looked in great details.

1.4 Focus Area

Globally, from 2005-2013, the major thermoplastics (the largest type by volume) industry grew by 45 million tonnes to 202 million tonnes (3.2% average growth annually). This is good performance since it is more than the global annual GDP growth of 2.3% in the same period. Their global consumption growth is expected to improve to 4.5% from 2013 to 2017. The Global Plastics demand could triple by 2050 and the potential volume is 600 million tonnes (i.e. 3 times the 2013 volume).

This performance is considered a good one since it registered values that were higher than the global annual GDP growth of 2.3% within the same period. The demand for plastics was revealed to be increasing at varying rates in different regions of the world depending on the different markets' maturities. Emerging markets like CIS (ex-Soviet Union) and Asia are expected to experience growth that is thrice as high as North America or Europe. In Malaysia, the plastics resins consumption grew at average of 3.7% from 2010 to 2013. This is significantly higher than the global average of 3.2%. Assuming Malaysia's 2050 plastics demand scenario is similar to the aforementioned Global 2050 assumption, i.e. triple the 2013 volume, than the potential volume is 6.6 million tonnes.

Currently, the key markets for composite industry are mainly in the aerospace, automotive, building & construction, wind energy etc. The estimated global market is USD70b and is growing at about 5% per year in value. Over the past three decades, the composites industry has seen long-term growth as a result of global economic development and higher rates of penetration into the key markets. The growth of the market is partly due to the development experienced by emerging countries, especially in Asia. It has a direct relationship to the economic health of these countries that are now in their equipping phase.

The key focus areas of the study are:

i. Trends for Advanced Materials
   - Cost effectiveness through moving from better properties to less material consumption with high output
   - Improving the performance of plastics component

ii. New Product Development
   - Improving products with the incorporation of sustainability elements
   - Moving towards high-end products

iii. Trends for Advanced Manufacturing Technology
   - Moving Industry towards energy efficient manufacturing processes
   - Rapid manufacturing technology
   - Overcoming processing limitations of polymer materials
   - Emphasis of precision controls on processing machinery
   - Emphasis of multi-skill, multi-discipline personnel

iv. Environment and Sustainable Development
   - Towards a holistic approach to sustainability
   - Adoption of LCA for products
   - Communicating the environment, safety and health aspects of plastics

iv. Education and Training
   - A pool of higher skilled workers has to be created for the industry

- Transform the industry from being an original equipment manufacturing (OEM) and turn it into an original design manufacturing (ODM) and even to an original brand manufacturing (OBM)
- A Centre of Excellence for plastics and composites has to be established

2.0 OVERVIEW OF INDUSTRY SECTOR *VIS-À-VIS* S&T FORESIGHT OUTPUTS

Changes in societies and global networks are being driven by global megatrends. The industry is seeing some key trends rising and starting to provide enormous potential. These trends have also started to generate growth in the new markets throughout the value chain and initiate unprecedented industry shifts. Plastics and composites are types of lightweight materials that have a vital role in facilitating the growth of many industries, such as electrical, automotive, packaging and building & construction. From the processing point of view they have many advantages: versatility in design; ease of shaping with less consumption of energy; incorporation of tailor-made properties to suit diversified range of applications; recoverability; and recyclability.

Most of human daily activities were made very convenient and so affordable due to the versatility of plastics and composites. For example, food packaging uses about 40% of all the plastics produced. Plastics are useful because they preserve food, reduce food waste and lessen packaging weight. Compared to other materials, plastic packaging's energy efficiency is unrivalled. Through the years, the plastics industry of Malaysia has shifted from being low-end consumer product manufacturers for import-substitutions into high-end manufacturers for industrial applications as well as for the export-oriented sector. The Malaysian Plastics Manufactures Association (MPMA) has stated that in recent years, the percentage of exports against sales turnover has risen significantly from approximately 40% in the late 1990s to around 60%.

The industries of plastics and composites have a vital enabling growth role for several industries like electrical, automotive, and building and construction. Malaysian Industry Government Group for High Technology (MIGHT) reported that local composites industry has grown from simple-product-for-construction to product-for-aerospace applications. Going into the future, the industry needs to leverage on these success factors as well as ensure continued success through enforcement of a government structured and in R, D & C roadmap that will build its resilience.

2.1 Performance of the Malaysia Plastics Industry

As of 2015, there has been continuous growth in the Malaysian plastics industry. Its total sales turnover that year went up to RM25 billion, a 27% increase compared to the RM19 billion earned in 2014. This increase, was, however, due to a revised method of compilation by the Department of Statistics, in which the real growth of the plastics industry should remain consistently at about 4% to 5%. There was a 8.5% growth in the export sector, increasing from RM11.94 billion in 2014 to RM12.96 billion in 2015 (See Figure 1). This increase can be mainly attributed to the export sector and this sector is considered as the main driver for the growth of the industry. This trend is expected to be maintained in the next few years.

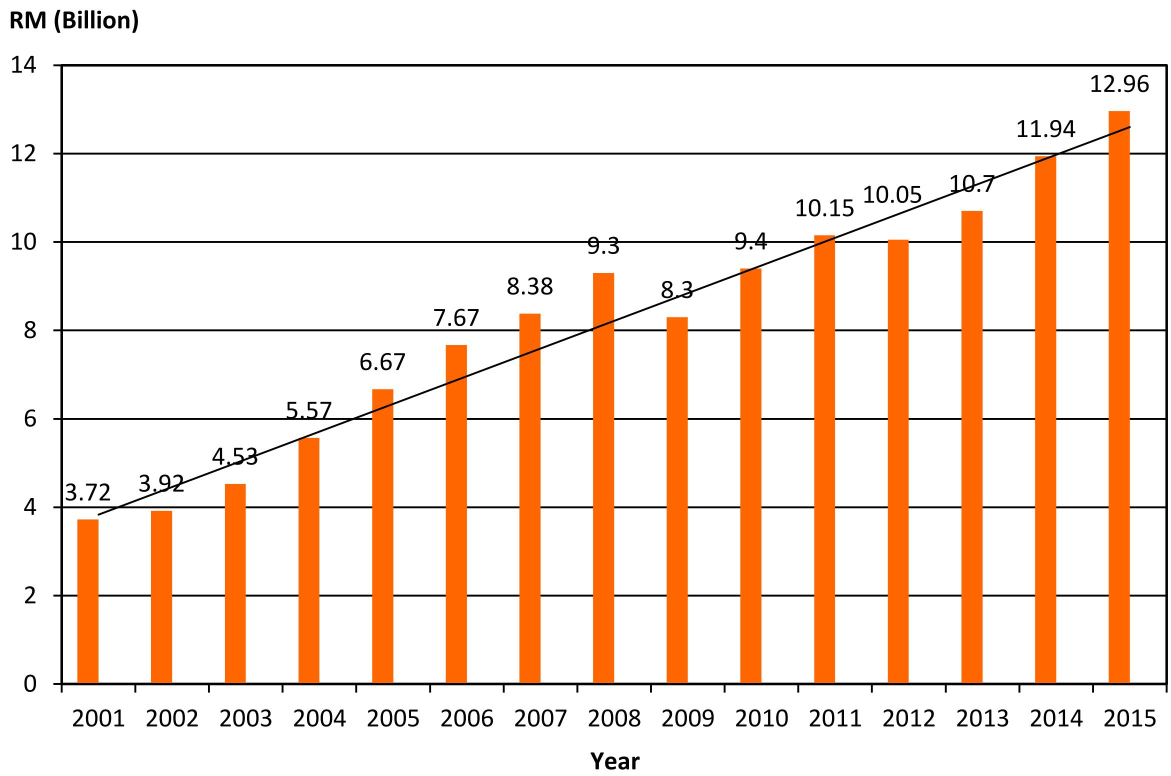

Figure 1: Export of Plastics Products (2001-2015)(MPMA 2016)

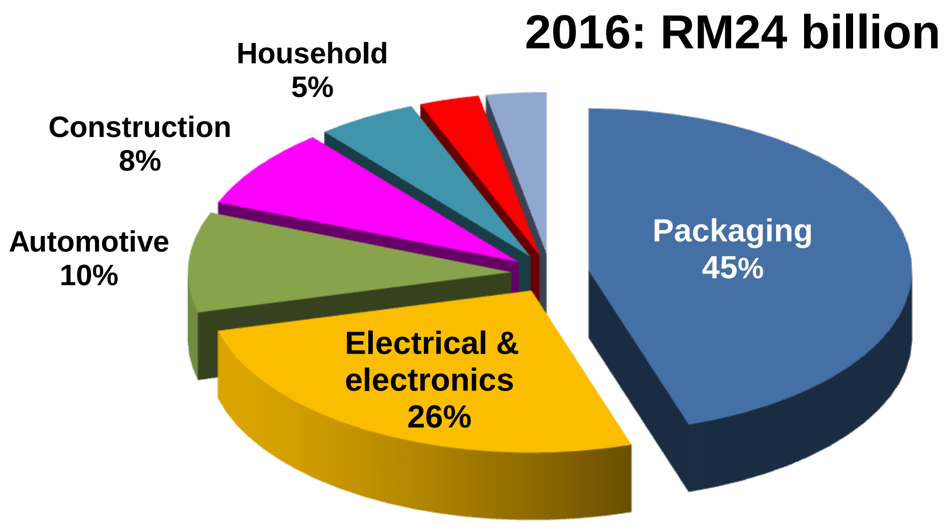

Figure 2 : Major Market Segments for Plastic Product (MPMA 2016)

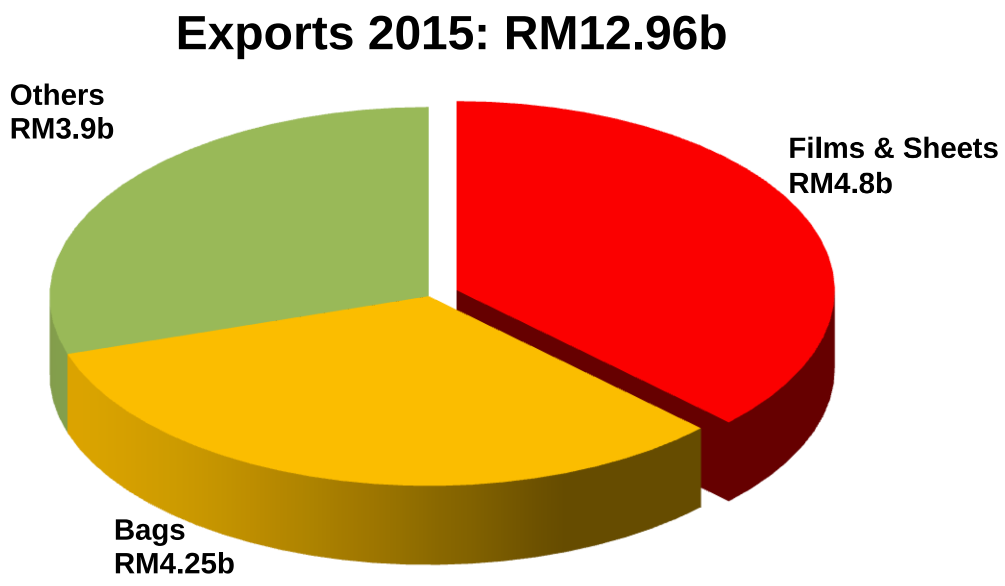

Figure 3: Main Exports of Plastic Products (MPMA 2016)

A 2015 report published by the Malaysian Investment Development Authority (MIDA) Report(MIDA 2015) revealed that the plastics sector had 43 approved projects in 2015, with equivalent investments of RM911 million. Out of this, thirty one are new projects that have a total of RM571 million investments. The rest were diversification and expansion projects amounting to RM340 million investments. Twenty two projects were entirely

Malaysian-owned (RM364 million), 11 projects were solely foreign-owned (RM175 million), and the last 10 projects were considered joint-ventures (RM372 million). These projects created 3,863 new jobs.

Moving forward, the plastics industry is expected to face challenges in managing rising costs, particularly, the cost of labour, limitations and rising cost of employing foreign workers, environment, safety and health issues, competition with the emerging economies, as well as the mild recovery in the economies in the European Union and Japan. The current major issues faced by the plastics industry during the period under review were labour issues, including the freeze in the intake of foreign workers, increase in foreign workers levy and other processing fees as well as the ban of certain types of plastic products imposed by several State Governments and City Councils.

2.2 The Malaysian Composite Industry

Because of recent technology innovations and manufacturing and product developments, composites are now becoming attractive options for numerous diverse applications. The Malaysian Industry-Government Group for High Technology (MIGHT) has revealed that in terms of volume, fibreglass has largely dominated (85%) composites, despite the significant rise in the utilisation of carbon and natural fibres. The matrix material for carbon fibre composites are largely (72%) epoxy. As for the Malaysia Composite industry turnover, it was estimated to be RM3.5b from a total of 70 fabricators. Currently, the largest application was Construction (43%), followed by aerospace (14%), and Marine (14 %) sectors.

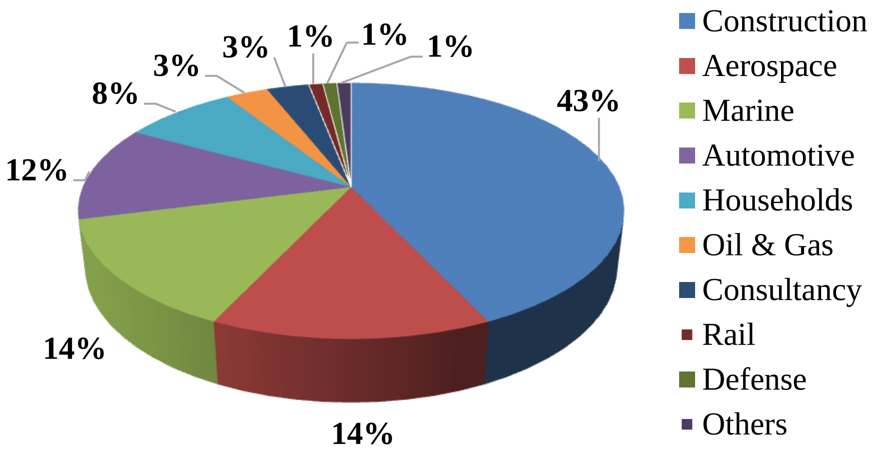

Figure 4: Composites Application by Sectors

Source: MIGHT analysis

Figure 5: Malaysian Composites Application

Fibre reinforced plastics (FRP) have been used in building and construction industry for many years due to its outstanding combination of mechanical performance and durability. Generally, FRP products in construction industry widely used glass fibre because this option is the much cheaper and more readily available. There are three major application areas: repair and rehabilitation applications, construction applications, and architectural applications. FRP is now being utilised for other construction-related applications as well, such as cable trays, walkways, handrails, ladders, doorframes, secondary structures, gratings, and water storage tanks. The construction of pedestrian footbridge using FRP is becoming popular worldwide. Apart from its light weight structures which allow for a quick assembly time, the FRP footbridges have been proven to be cost-effective in term of corrosion resistance, long-term maintenance cost.

Figure 6: FRP Pedestrian Bridge in Lleida Spain (Summerscales 2016)

The pedestrian bridge found in Lleida, Spain is considered the longest arch bridge. Its tied-arch measures 38 m long. It has a 6.2 m rise, and a deck that is 3 m wide (see Figure 6). The bridge was constructed entirely using GFRP pultruded profiles. Fabrication of the bridge was done in only three months. It was then erected using a crane in just three hours. This pedestrian bridge covers the Madrid-Barcelona high-speed rail link. In 2005, it won the international “Footbridge Award” under the “Technology” category, which was specifically for bridges with medium span measuring 30m to 75m. FRP that utilises glass fibre was used for this bridge since it is an electrical insulator. Moreover, it gets rid of the magnetic interference from the electrified railway. In Malaysia, there are many opportunities to use composite bridges either in urban or rural areas. Thus the composite industry needs to work closely with regulatory agencies such as local authorities; CIDB and Department of Standards.to create more opportunities for application of composites in construction industry.

As of now, offshore E&P facilities like underwater subsea systems and platform structures have been mostly designed and constructed with conventional materials i.e. steel and concrete, in mind. These materials have long service lives and low maintenance requirements. They are also good alternatives for expensive corrosion-resistant metals like copper-nickel alloys. Composite materials are more superior when it comes to corrosion resistance, and thus they help increase safety and reliability while lowering life cycle costs. Phenolic resin pultruded structures are known to be really good at retaining significant functionality even after fire exposures while being able to maintain low levels of smoke emission. It has been utilised for many non-load bearing applications and secondary structures like gratings, handrails, processing vessels, high- and low-pressure tubing, and water tanks.


Figure 7: Applications of FRP in Offshore E&P activities (Philip Medlicott Ltd 2012)

Composite grids/gratings have better performance under aggressive offshore environments because they have better corrosion resistance, durability, weight, and lower lifecycle costs. Throughout the world, numerous manufacturing companies around the world produce compression moulded or pultruded composite gratings. They are often used as industrial walkways, cable trays, hand-rails, etc. The use of filament-wound carbon fibre/epoxy composites in high-pressure vessels has proven that composites can also be used in a cost-effective and safe manner even in bigger, primary load-bearing offshore structures. Despite the fact that composite materials have been used in other industries for a long time, there is still some resistance when it comes to their application in the oil industry.

More information regarding the handling and installation of these materials is needed. As of now, there are not enough test data that can provide information on the materials' long-term durability and shed light on regulatory issues that can be uniquely encountered in offshore systems. Before the full potential of these offshore composites can be achieved, considerable efforts have to be taken. Globally, guidelines and standards are now being issues by certification agencies to accelerate the acceptance of major offshore composites.

In Malaysia, composite products are finding increasing penetration into offshore applications. The composites industry should initiate by providing dependable, large-scale capabilities for manufacturing composites. In order for the results to be accepted by regulatory and certification agencies, further discussion and cooperation must be practiced by various agencies.

The MIDA Report, 2015 (MIDA 2015) has stated that the aerospace industry's significance has been further reinforced under the 11MP. Its strong inter-linkages with other sectors as along with their numerous multiplier effects will improve the aerospace manufacturing ecosystem's development, from MRO to composite materials and even metallic parts and components. As Malaysia slowly starts becoming a hub for aerospace companies, it can assist in providing other original equipment manufacturers (OEMs) opportunities to complete their supply chains and fast-track local SME participation in the global market. The aerospace industry of the nation is expected to rise with the help of the Aerospace Blueprint for 2015-2030 as a guide (MiGHT 2015).

The plastics and composites industry has been proven to perform well and continued to follow and initiate transformative innovations in the automotive industry. The P & C industries are putting all their efforts to address the changing needs of the automotive industry. As of now, the automotive industry is facing increased pressure to meet the demands for higher fuel efficiency, and improved performance and environmental impact at competitive costs. In North America, the automotive market's most influential force is the standards of the joint Corporate Average Fuel Economy (CAFÉ) set by the US Environmental Protection Agency and the National Highway Traffic Safety Administration. These agencies set emissions and miles per gallon (mpg) requirements to more than 50mpg (about 21.25km/l) for model year 2025 vehicles**.** The need for high stiffness-to-weight and strength-to-weight ratios and excellent energy absorbing capacity per unit mass was also specified. The American Chemistry Council also came up with a Plastics and Polymer Composites Technology Roadmap intended for automotive markets (ACC 2014). It states that by 2030, plastics and polymer composites will be recognised by the automotive industry and society as preferred material solutions that satisfy, and even set, sustainability requirements and automotive performance.

Locally, with the National Automotive policy (NAP) 2014 (MITI 2014) as a guide, the automotive industry is predicted to contribute a total of 10% to the country's GDP by 2020. The production of vehicles is expected to rise to 1.35 million units (cf. from 614,464 units in 2015) and creating additional 150,000 employment opportunities..

3.0 FORESIGHT STUDIES ON PLASTICS AND COMPOSITES INDUSTRY

Most foresight studies have a tendency to examine the nations' overall technology requirements in the coming decades. In 2007, Canada formulated a technology road map for its plastics industry. One of its recommendations is making sure that "the coming years will be guaranteed by stability from the aerospace & defence sectors, wind turbines and sport/leisure sectors, and to a certain extent, the construction and automotive industry. Among the challenges that have to be addressed are cost-cutting, automation, and the formulation of manufacturing processes that are appropriate for mass production and respectful of ecological aspects.

In the UK, in about the same year, the National Composites Network of UK has undertaken a Foresight study for the UK Composite industry to identify long term needs of the industry in terms of advancement of the technology to enhance competitiveness. The desire was to enhance the nation composite capability to compete against rivals on the basis of a superior technology base. The reports focus the following generic sectors of the composite industry: defense and aerospace, rail, automotive, process plant, construction and marine.

In 2008, Thailand developed the Bio Plastic roadmap under the purview of The National Innovation Agency (NIA) (NIA 2008). The expectation was that by pushing into the Bio Plastic, the strategy will not only develop the plastic industry, but also help to develop other downstream industries grow, particularly the food industry that need plastic items for packaging.

In 2014, the German Federation of Reinforced Plastics issue the Global and European Composites Market Report highlighting the market developments, trends, challenges and opportunities for the Composite industry (Witten & Thomas 2014). It was expected the carbon composites industry to continuously grow at about 10% in the coming years with stability guaranteed by the sectors aerospace & defense, wind turbines and sport/leisure and to certain extent, by the automotive and construction industry. Among the hurdles need to be addressed will be automation, cost-cutting and the development of manufacturing processes suitable for mass production as well as the ecological aspects.

In the national arena, the Malaysian Plastics Manufacturers Association (MPMA) also formulated a roadmap using inputs provided by participants from the plastics industry. The roadmap's vision is to turn the plastics industry into one that can compete at a world-class level by 2020 through value creation, and progressive and sustainable development.

Additionally, it will as serve as a guide for plastic processors to satisfy the requirements of the government's New Economic Model (NEM). The NEM has emphasised the need to have a quality workforce by improving and increasing industry-driven training and formulating programs to upgrade skills. It also emphasised on innovative processes and innovative technology for high value-added goods while lessening the dependency on foreign labour.

In Malaysia, some government agencies have also undertaken the same initiatives for composites. The industry development has been guided by the National Industry Development Plan or the 3rd Industrial Master Plan (2006–2020) and the National Aerospace Blueprint for 2015–2030 (MiGHT 2015) (MITI 2006). It is therefore timely for the ASM to spearhead another study for the next 35 years for the nation.

In order to achieve this vision, the roadmap has stated that plastics manufacturers must employ and pursue the following strategies: improving market speed significantly, developing new applications, addressing sustainability issues, and enabling infrastructure. In order to achieve this strategy, the roadmap’s focus is on five core areas: Advanced Materials; Advanced Manufacturing Technology; New Product Development; Sustainable Development; and Education and Training. For this Mega Science Agenda on Plastics & Composites sector, the basic methodology for this study consists of primary research (direct consultation and intensive engagements with experts in the field of Plastics & Composites) and secondary research. (Review of published data and established information sources).

Consultations have been undertaken to include leading industry players, general SME’s, industrial associations, R&D and academia institutions. The collaboration between industry and academia is important in improving the alignment between the supply and demand of skills. It is also vital in encouraging knowledge sharing and industry research. Innovation via R & D activities acts as a catalyst in value creation through the development of new materials, and products, new manufacturing technology and intellectual property in the form of patents. Workshops for Foresight Exercise with the plastics and composite experts have been undertaken together to generate ideas and facilitate consensus among experts who have special knowledge to share.

Industry workshops to achieve a consensual view on the future of the industry were undertaken using tools such as Foresight and Gap analysis. It is also essential to consider the external forces that affect the plastics and composite industry before long term proposals can be formulated.

3.1 Overview of Industry Sector *vis-à-vis* Foresight 2050 (impact of social/culture/economics/geopolitics on industry)

The plastics industry of the future is not business as usual. It's a paradox that the plastics industry is victim of its own success. Rapid growth in utilization invariably leads to greater amount of improper disposal leading to increasing environmental problems. At the global scale, the world nations have unanimously agreed that some serious actions have to be taken before it's too late, to the detrimental of our own future generations.

In September 2015, all the 193 members of the United Nations has agreed to adopt the 2030 Agenda for Sustainable Development. The World Economic Forum released a report about the industry agenda for plastics under the theme "The New Plastics Economy: Rethinking the future of plastics" (World Economic Forum 2016). In this ground-breaking report, the circular economy was proposed as a potential strategy that the plastics industry can use to move forward. The goal is to increase prosperity, while minimising negative externalities and lessening the demands on finite raw materials.

In order to have virtuous instead of depletive cycles, there is a great need to alter the current production and consumption patterns. Thus, the sector has to act immediately. By taking advantage of the fact that they can utilise communications technology, global interconnectedness, and advances in materials science, the P&C sector will work hard to make sure that the industry is sustainable by 2050.

The P&C sector needs to address these global agreements. Moreover, because of the sector's scale and sheer pervasiveness, it should be able to answer questions as to what direction it should take. Despite this sector's numerous tangible and substantial benefits, it also has several drawbacks that are important, long-term and too apparent to not pay attention to.

3.2 The New Plastics Economy Demands a New Approach

The vision of the New Plastics Economy is for plastics to never be wasted. This new economy aspires that plastics can enter the economy again as valuable biological or technical nutrients. The New Plastics Economy must adopt and be aligned with the principles of a circular economy. For example, while plastic packaging and products play a vital role in our society, plastic wastes should never be detrimental to our land and ocean and to wildlife and humans. Moreover, there is enormous plastic loss from today's plastics economy and it is becoming a source of economic drain.

Thus, we have to address and find a solution to the problem of plastic waste now. There are many solutions, however. One major solution is practicing better waste management and reducing the occurrence of single use plastics. This problem can be solved by using a circular economy approach, where instead of becoming waste, used plastics become feedstock (World Economic Forum 2016). To come up with a sustainable system of producing and using plastics and plastic packaging, one has to take into account the unique opportunities and challenges that can arise from the collection, use, and reuse of the material. It signifies the need to take action to start an ambitious redesign that has a longer term view of the potential value while promoting intensive collaboration among different players.

3.3 Issues & Opportunities of Plastics Packaging

Plastics packaging is an important part of delivering safe and high-quality consumer products. However, we have to radically rethink our views on how we utilise plastics. We have to start new circular systems that will help save resources, promote efficiency, and reduce pollution.

After the release of the report Towards the Circular Economy: Accelerating the Scale-up across Global Supply Chains in January 2014, the World Economic Forum has partnered up with the Ellen MacArthur Foundation and gained the support of McKinsey & Company to create Project Mainstream. This project is a collaborative effort that could help businesses move towards a circular economy and help the industry conserve $1 trillion in materials every year by 2025. It could also prevent the production of 100 million tonnes of waste globally (Ellen & Kailash 2015).

Project Mainstream has identified plastic packaging as the first area that needs action. The "plastics" economy has remained tremendously linear despite numerous recycling initiatives; even for polyethylene terephthalate (PET), the most recycled plastic packaging material, 93% is still produced using virgin sources. By 2015, Mainstream will collaborate with manufacturers, recyclers, retailers, and cities to formulate and use principles towards creating an economy that will not waste plastic packaging and instead allow it to re-enter the economy as an important technical or biological nutrient. The win from this effort is potentially huge. Currently, $2.7 trillion worth of plastic materials is still being "lost" from the economy. Majority of this loss in packaging comes from fast moving consumer goods such as home/personal care products and food/beverage goods that are often disposed after a single use (Ellen & Kailash 2015). The economy and the environment will benefit greatly if all this waste is turned into an asset. Moreover, new jobs will be created in the process as well.

PET and polyester's annual material demand amounts to approximately 54 million tonnes. Of this, about 86% (roughly 46 million tonnes) ends up leaking out of the system. If Project Mainstream can create a foundation to allow the recycling of polyester – which is already being collected but ends up getting either burned or landfilled – the amount of non-collected polyester will be lowered by 10% and almost $4 billion in value will be generated (Ellen & Kailash 2015).

As of now, being able to scale up this process is difficult because of its high cost and the availability of cheaper petroleum-based PET monomers like purified terephthalic acid (PTA) and mono ethylene glycol (MEG).

In 2011, about 7.5 million tons of PET was collected worldwide. This is equivalent to about 5.9 million tons of flakes. In 2009, 3.4 million tons were utilised for fibre production (generally for textiles & clothing - See Figure 8), 500,000 tons for bottle production, 500,000 tons for APET sheet production to be used for thermoforming, 200,000 tons for strapping tape production and 100,000 tons for other applications (Source: PCI, www.pcipetpackaging.co.uk) (Wikipedia 2016).

Figure 8: 8 recycled plastic bottles: 1 football shirt (Beard 2011)

Petcore, a European trade association that facilitates PET collection and recycling, has stated that 1.6 million tons of PET bottles were collected in Europe alone in 2011; this accounts for over 51% of all bottles. Taking into account the exported bales (mainly to China) as well, it was revealed that 1.12 million tons of PET flakes have been produced. 440,000 tons of these were used for fibre production, 283,000 tons for bottle production, 278,000 tons for APET sheet production, 102,000 tons for strapping tape production, and 18,000 tons for use in other applications (Source: PCI for Petcore and EuPR) (Wikipedia 2016).

In 2008, the United States collected and recycled about 1.45 billion pounds of PET bottles. In 2012, Switzerland recycled 81% of the PET bottles that have been sold that year. Increasing prices for energy prices could also result into an increase in the volume of recycled PET bottles. Europe's EU Waste Framework Directive has instructed that by 2020, 50% of plastics from household streams should be recycled or reused (Wikipedia 2016).

Normally, plastics can be recycled into plastic lumber, roadside curbs, tables, benches, trash bags & receptacles, truck cargo liners, stationery (e.g. rulers), agricultural films & nursery bags, and other heavy-duty plastic products. Moreover, these products are in good demand.

3.4 National Technology and Industry 2050 Business Outlook – Scenario Building (based on findings/feedback obtained during Stakeholder Engagement)

Globally, from 2005-2013, the major thermoplastics (the largest type by volume) industry grew by 45 million tonnes to 202 million tonnes (3.2% average growth annually) . This is good performance since it is more than the global annual GDP growth of 2.3% in the same period. Their global consumption growth is expected to improve to 4.5% from 2013 to 2017. The Global Plastics demand could triple by 2050 and the potential volume is 600 million tonnes (i.e. 3 times the 2013 volume).

Based on different market maturities, the demand for plastics has grown at various rates in different parts of the world. Emerging markets such as Asia and CIS (ex-Soviet Union) are expected to have growth rates that are three times higher than Europe or North America.

In Malaysia, the plastics resins consumption grew at average of 3.7% from 2010 to 2013. This is significantly higher than the global average of 3.2%. Assuming Malaysia's

2050 plastics demand scenario is similar to the aforementioned Global 2050 assumption, i.e. triple the 2013 volume, than the potential volume is 6.6 million tonnes.

Currently, the key markets for composite industry are mainly in the aerospace, automotive, building & construction, wind energy etc. The estimated global market is USD70b and is growing at about 5% per year in value. Over the past three decades, the composites industry has seen long-term growth due to better penetration into the key markets and improved global economic development. The growth of this market can be partly attributed to the development of emerging countries, especially in Asia. Moreover, this growth is directly related to the health of these countries' economies, especially now that they are in the equipping phase.

3.5 The key focus areas of the study

3.5.1 Trends for Advanced Materials

Advanced materials are vital materials for everything from everyday household products to critical defence applications. The high level of global R&D investment in advanced materials is proof of their importance. A relatively new method to integrate information about materials using engineering performance analysis, computational tools, and process simulation has shown great potential in optimising manufacturing processes, materials, and products.

Currently, research activities address the development of (multi)functional materials. They are also known as intelligent, smart and responsive materials. The attribute 'functional' refers to a combination of properties which are essentially independent of each other. Accordingly, the related materials – apart from the required load bearing capability – exhibit 'functional' properties, such as shape memory, self-healing, sensing/actuation, electric conductivity and reprocessability (J. Karger-Kocsis 2016).

These and other recent advances in resin materials, improved automation, and factory connectivity all point to a bright future for plastics manufacturing. Researchers working at Harvard University's Wyss Institute for Biologically Inspired Engineering have managed to create a new material that can mimic the outstanding toughness, strength, and versatility of insect cuticle, one of nature's more exceptional substances. The new material called "Shrilk" is low-cost, biocompatible, and biodegradable. In the future, it could become a replacement for plastics in consumer products and they could even be utilised safely in various medical applications (J. Karger-Kocsis 2016).

These and other recent advances in resin materials, improved automation, and factory connectivity all point to a bright future for plastics manufacturing. Researchers at the Wyss Institute for Biologically Inspired Engineering at Harvard University have developed a new material that replicates the exceptional strength, toughness, and versatility of one of nature's more extraordinary substances -- insect cuticle. Also low-cost, biodegradable, and biocompatible, the new material, called "Shrilk," could one day replace plastics in consumer products and be used safely in a variety of medical applications (J. Karger-Kocsis 2016).

A report written by Professor Patrick Grant of the University of Oxford entitled "New and advanced materials" has stated that in the plastics industry, a progressive shift has been observed from companies that provided mainly distinct material classes like polymers, metals, or ceramics to enterprises that can provide finished components and systems for use in energy, medical, aerospace and various other sectors that are now dependent on new integrations of the newest materials developments (Grant & Mason 2013). The future trends seen for new and novel materials are based on the following industrial and societal needs:

i. Materials security and sustainability
ii. Materials needed for energy
iii. High value markets that represent the current priorities concerning advanced materials

The review has revealed that it is unlikely for future novel materials to possess high intrinsic value. Instead, value can be gained in the manner by which new materials will be incorporated into systems and components so as to enable new designs and provide better performance. Moreover, separating manufacturing innovations from materials developments has been hard since they push each other into a virtuous improvement spiral geared towards achieving optimum performance. The greatest material developments in the future will involve the seamless integration of "new" and "old" materials with improved precision and increased sophistication, even when done at a nano-scale. Some of these examples include materials for functional coatings, drug delivery, and energy storage and solar power devices (Grant & Mason 2013).

Consequently, most of these future materials' value will depend on the ability to function competitively while balancing and optimising the combination of materials science, design, and manufacture. Design now plays an important part in gaining access to the more important parts of the materials supply chain. Thus, modelling and simulation, specifically design- or model-led experimentation, will have a larger role in materials development.

These approaches can be utilised along with the increasing range and capability of in-situ and micro-mechanical testing. These methods can provide data on key materials quickly while only needing minute amounts of material. As a result, it provides potential chance for the industry to drastically shorten the design-make-test cycle, which currently sets the timing of the deployment of new materials. This approach could be advantageous in the development of better structural materials that can be used for fossil fuel and for the generation of nuclear based energy. Still, even in the laboratory or in simulations, this quick development of materials should still find a way to identify materials that can be manufactured at a given scale and cost that matches the current market demand.

Additive manufacture also provides great opportunities to innovate materials. However, it is still restricted to its low rates of production and to an operation that is only applicable within a narrow range of alloys and polymers that are typically set by the machine manufacturers. Thus, the focus of future materials research should be on gaining a better understanding of how to manage microstructure, yield, shape, and residual stresses in this process family so that additive manufacture can begin to utilise a wider range of materials (Grant & Mason 2013). The knowledge gained from this should then be applied in the development of new approaches related to the additive manufacture of graded components multi-material structures within a single step. Amongst the numerous possibilities, a multi-materials approach may enable novel and drastically improved performance of active bio-structures and meta-material based devices.

i. Materials security and sustainability

- Materials that have lower environmental impact through-life
- New processes and materials technologies that will support higher materials recirculation (Grant & Mason 2013)
- Materials that can be used for ensuring the sustainability of resources: bio-derived materials

ii. Materials for energy

- Nuclear power generation and fossil fuels
- Generation of renewable power
- Storing energy
- Energy

iii. High value markets

- Graphene, carbon nanomaterials, and 2D nanomaterials
- Biomaterials
- Electrical materials

3.5.2 New Product Development

i. The manufacturing industry will be driven by reverse engineering

These days, it is possible to reconstruct and improve virtually anything. The manufacturing history has shown that innovation has always relied on the capacity to make certain adjustments until a newer and better product is created. After the recent recession and recovery, the manufacturing industry has learned to be more efficient and more adept at finding new opportunities from existing products. More manufacturers are expected to apply this mentality to plastics. Through "reverse engineering," it is possible for manufacturers to build on existing information and bodies of knowledge by examining a completed product, disintegrating it, understanding how it works, and creating improvements. This is something that is normally done for products and parts that are no longer produced or those that have to be examined for potential weaknesses or defects that have to be redesigned. Reverse engineering is advantageous because manufacturers do not need to reinvent every time. Instead, manufacturers can determine what features are working and make adjustments so that a part can be made to perform better or so that they could create something new entirely. This principle has been implemented on a large scale and even for customised orders. Moreover, it has been gaining popularity since customers are the ultimate beneficiary and they are interested in finding solutions using more cost-efficient ways.

ii. Precision Parts Are On the Rise

The demand for precision parts is likely to increase as customers adjust to a new age of repeatable and customised manufacturing. By 2015, more focus will be given to complex plastic components and incredibly accurate manufacturing methods. It is being considered as a new innovation age. Thus, there will be high demand for everything from customised plastic gears bearings and sprockets to clamps.

iii. Continued acceleration of the production of parts for electronics

The demand for electronics from consumers has remained strong. In fact, some sources have claimed that in the last decade, it has experienced an increase of nearly 150% (Steve Kline 2014). In 2014, an increase in disposable income and steady growth in consumer spending was experienced. These trends usually affect the electronics industry positively. Moreover, lightweight, sturdy plastics have increasingly been integrated into consumer electronics; this includes outer casings, internal components, and more. This are all great signs for the plastics industry, as it is helping pave the way for manufacturing comeback in the U.S.

iv. 3D printing will reveal its staying power

Some have thought of 3D printing as a passing fad, but the occurrences in the past few years have proven the opposite. 3D printing is actually a decades-old technology, but it made headlines in 2014 in its applications and new medical uses. The increased public interest is helping it become a staple in manufacturing plastics. Companies are now utilising 3D printers to produce new medical devices and prosthetic body parts. Toys and tools are being created using this technology; even the aerospace industry has given more attention to this quickly evolving field. More interesting is the fact that it has also penetrated the consumer market. Consequently, manufacturers have started investing in the technology as well. Moreover, it has been shown to be a user-friendly technology that is highly precise and versatile, allowing for new designs to continuously be produced. It is for these reasons that the 3D printing trend is expected to go into 2015 and beyond.

v. Manufacturing will become smarter

One may anticipate the pending robotic revolution in manufacturing (automated everything) and how manufacturing is getting ever leaner, faster and more efficient.

But there's more to the manufacturing technological boom than that. The process itself is evolving, with or without robots. And that's because we are quickly learning how to collect and use valuable data related to process. Sensors are increasingly important in manufacturing as they give invaluable data for improving efficiencies and reducing potentially costly errors. And wireless technology is increasing our ability to place and use those sensors. In the future, there will be leaps and bounds in the world of sensors; and consequently, one may expect even more streamlined processes that result in better products.

3.5.3 Trends for Advanced Manufacturing Technology

Future Trend in advanced manufacturing points to an increasingly automated world that will continue to rely less on labour-intensive mechanical processes and more on sophisticated information-technology-intensive processes. This trend will likely accelerate as advances in manufacturing are implemented. Advanced manufacturing scenarios for the Short Term and Long Term out are outlined below:

i. Short Term

- As digital supply-chain management and automation become the standard among enterprise systems, manufacturing in turn will be more globally linked. This can be done by adopting adaptive sensor networks that can produce intelligent feedback that is capable of relaying analyses and decision-making in real-time. The shift to cloud sharing is expected to become the "computing commons" that will be utilised by small and medium manufacturing enterprises. Consequently, there will be a need to manage and secure large amounts of data that will be produced in the supply chain and manufacturing facility. Moreover, the need to ensure cyber-security of globally linked enterprise systems will arise. Simulation and modelling will lead to faster development of new products, materials, and processes in various fields such as nanoelectronics, integrated computational materials engineering (ICME), and synthetic biology.

- Countries and companies that will start to invest in cyber infrastructure and related physical infrastructure are more capable of taking the lead since they can take advantage of the increased flow of information. In turn, the underlying expansion in sensing and computing capabilities will increase the importance of semiconductors in such a way that it will go beyond the sectors of computing and information technology. Intelligent sensor networks will pave the way for the creation of more autonomous systems across sectors, such as energy management, transportation, and health. The utilisation of large datasets will depend on more sophisticated approaches to analytical tools and visualisation that can then accelerate discovery, detect patterns, and lower risk.

- The rising demand for customisation and flexibility could result into the spread of additive (3D) manufacturing for integrated computational materials engineering and customised geometry for customised materials. These trends will make it possible to practice local manufacturing that can adapt to the region's needs while still having the flexibility for global market production. Manufacturers will be able to distinguish themselves by how well they can utilise data and how creative they can be in marketing and designing new products. New tools will help manage the analysis of large data sets to accelerate discovery, detect patterns, and lessen risk.

- When viewed from a technological standpoint, improvements and advancements in materials and systems design can possibly transform and accelerate manufactured products. For instance, large global investments in carbon nanotubes and graphene for use in nanoscale applications can potentially alter applications in electronics and renewable energy. Moreover, as technologies improve and cost-effective implementations are implemented, biologically inspired designs and self-assembly-based fabrication processes will be incorporated into the manufacturing process.

- Many countries will focus on establishing an advanced manufacturing sector. Their progress will be greatly influenced by market factors. Companies will aim to set up in countries that potentially have large and growing markets. By formulation country-specific policies that can foster advanced manufacturing, manufacturing sectors can more easily establish themselves in both developed and developing countries

- Advanced manufacturing processes will likely be more energy and resource efficient, as companies strive to integrate sustainable manufacturing techniques into their business practices to reduce costs, to decrease supply-chain risks, and to enhance product appeal to some customers.

ii. Long term

It is expected that in the next 30 years or so, majority of the early trends and techniques that started to develop at 10 years will be more fully adopted, and advanced manufacturing will be geared towards new frontiers.

- Manufacturing innovations will displace many of today's traditional manufacturing processes, replacing labour-intensive manufacturing processes with automated processes that rely on sensors, robots, and condition-based systems to reduce the need for human interventions, while providing data and information for process oversight and improvement.
- Advanced manufacturing will increasingly rely on new processes that enable flexibility such as biologically inspired nanoscale fabrication processes and faster additive manufacturing techniques capable of building at area or volume rather than by layering materials.
- Manufacturers will increasingly use advanced and custom-designed materials developed using improved computational methods and accelerated experimental techniques. Advances in design of materials will rely on a combination of computational methods and accelerated experimental techniques to decrease the time from concept to production. The coordination of materials designs, processing, and product engineering will become more efficient as computational abilities continue to improve.

  Integrated computational materials engineering and additive manufacturing processes will begin to replace traditional processes. This will have the added benefit of integrating sustainable manufacturing processes by reducing use of resources and eliminating waste across the manufacturing enterprise. Additive manufacturing will allow for increasing manufacture of customized products. In 30 years, advanced manufacturing is expected to be heading toward atomic-level precision-manufacturing processes.

3.6 Top Trends for Plastics Manufacturing

Below five key trends that are possible for plastics manufacturing will have significant impacts not only on the plastics industry but the world of manufacturing are outlined

3.6.1 Lightweighting

Plastic resins and additives will continue to be on the forefront of advances in light-weighting from heavier metals to plastic. The auto industry has embraced this trend for years and it will continue to influence how all products are manufactured. Along with improved product designs, engineers will work with molders and resins suppliers to customize special formulations that meet the specific needs of a project. Look to see plastics replacing many forms of metal in products large and small.

These new lightweight materials have been tested in automobile impact studies, and are now beginning to migrate into other products that require durability. Sports equipment, like helmets and boots, use these new polymers. The construction industry has long embraced plastics and this trend will continue. New plastic building components will come on the market to replace wood, steel and concrete. Axion, an Ohio-based company, is using recycled plastics to create structural components for buildings, bridges, and railroads (Axion International 2015). And, one tiny house project is made almost entirely from plastic building products creating the house envelope and interior details. Even the roof is made from plastic shingles with solar cells built in.

3.6.2 Automation and Customization

Automation and robotics in factories have been around for years. Often used in highly industrial applications, manufacturing robots have become more agile and adaptable. The new automated factory will utilize collaborative robots equipped with vision systems that can be easily trained to perform various tasks. It is costly to reconfigure a manufacturing cell and corresponding processes with every production-line design change. These robots give manufacturers more flexibility.

More sophisticated robots will also increase the ability to customize manufactured products, from jeans to medical devices. In the future, PAM or Purchase Activated Manufacturing will be a mainstay in American commerce and will rely almost solely on robotics and automated processes. As an example, BWM gives customers the flexibility to order the car of their dreams with options in exterior and interior colors, engines, and upgrades. Their website claims the South Carolina facility could run a nearly 24/7 operation for six months and not produce the same car twice (Worth 2016).

3.6.3 Three R's - Reclaimable, Recyclable, and Renewable

In the U.S., we have made great strides in first reclaiming plastics by sorting, whether at home or at work, and have increased our recycling efforts as well, finding more uses for the re-ground and recovered materials. However, plastics recycling rates are much higher in countries like Japan, in 2011 it was at 77%, which is about twice that of the UK, and well above the 20% figure for the US, which still depends largely on landfill (World Economic Forum 2016)

In Europe, approximately 58% of all composites and plastics waste is currently being recovered and 24% of that gets recycled and turned into new products. The remaining 42 is disposed and went to landfills. As for Malaysia, the current amount is approximately 220,000 tonnes/year, or 600 tonnes/day, at 12% recycling rate for plastics. This constitutes about 15% of waste in Malaysia from the total wastes amounting to about 33,000 tonnes/day. Globally, recycling plastics is becoming a lucrative business, with 8 million tonnes of plastics being utilised for energy recovery.

The real challenge is creating renewable materials (also called bio-based plastics) that no longer depend on fossil fuels. Many companies are starting to take a serious look at these alternatives. Thermoset plastics, which are often used in automobile or large part molding, are not recyclable. In response, companies like John Deere are developing new composites using soybeans and flax (John Deere 2016). The cost, structural and design advantages of these new plastics have helped secure John Deere as a leader in their industry.

Islands of plastic debris floating in our oceans highlight the serious nature of our plastic dilemma. The issues and solutions on marine debris or litter are discussed in section

2.3.4. The solutions include the new circular plastics economy and that biodegradation is not a solution for marine litter.

It is clear, especially in the new circular plastics economy, efforts are needed to decouple or to reduce plastics made from petroleum-based compounds. The plan is to move to renewables, bio-based or controlled biodegradable alternatives that can fully compost back into the soil.

Nonetheless, it is noteworthy that current trends showed renewable or bio plastics complement rather than compete or to completely replace petroleum based ones. Dupont, a leader in bio-based alternatives has created Sorona® from corn. This new polymer is used in carpets and clothing. However, Sorona® only contains 37% renewably sourced ingredients by weight while 67% is petroleum based. It is neither biodegradable nor compostable (Dupont.com). Hence, the selling points are Renewable or Bio content and Durability not Biodegradability or Compostability.

Furthermore, researchers at Harvard's Wyss Institute were able to develop a fully biodegradable plastic made from chitin, a substance that is abundant in shrimp shells. Similar work is also being done in the EU under project n-Chitopak(EU Horizon 2020). It claims developing plastics having bio-degradable, compostable and antimicrobial properties suitable for many applications. The potential is huge (Globally about 150 million tonnes of shellfish waste are produced annually) but still at pilot stage with cost performance, economies of scale and sustainability yet to be proven.

3.6.4 Near-Shoring

While the debate goes back and forth between reshoring advocates and naysayers, one trend that can't be denied is near-shoring. Companies throughout the world have realized that getting closer to the source of their products just makes sense.

It is not surprising that IKEA, the popular Swedish furniture manufacturer and retailer has a large facility in Danville, Virginia. The raw materials needed for furniture including timber are close at hand as are the U.S. consumers that purchase IKEA products. In the Middle East, GE has invested in expanding their manufacturing facilities in Saudi Arabia to help serve the Saudi electric utility market. This industrial contract is a lucrative one for GE and they want to make sure their client gets the attention they deserve (Worth 2016).

The benefits of near-shoring manufacturing strategies are numerous. Companies can act quickly in response to trends and consumer demand; they can create a more efficient manufacturing process, and reduce logistics costs (The Rodon Group 2016).

3.6.5 The Connected Factory

Factories in the past had entrenched operational silos with gatekeepers often keeping a tight fist on their sphere of control. That model has all but disappeared from the American manufacturing landscape. Manufacturers today need to be able to respond quickly and adapt to their customer's needs. They are changing the way they operate to become more efficient and responsive.

Over the past decade, many companies have invested heavily in connecting all facets of their manufacturing process from design and development to logistics. They have become much better at using technology and connected devices to find and resolve production issues quickly. By connecting all of the manufacturing systems, managers can troubleshoot problems reducing downtime and costs.

The greatest challenge for many factories is to find the right technology solutions to connect all of their factory assets. Utilizing the Internet of Things, factories will become more reliant on networked devices, sensors, and digital communications to improve productivity and control costs from remote locations.

In the U.S., 69% of all the business R&D is performed by the manufacturing sector. This, in turn, is driving a revolution that is not only directing growth in manufacturing but in the broader economy too (Worth 2016). There are three key developments that describe the manufacturing revolution:

i. In the Internet of Things, machines have sensors embedded in them. These sensors relay information that makes it possible for them to work together and report imminent maintenance issues before a breakdown takes place.
ii. Advanced manufacturing includes new materials, 3-D printing, and the "digital thread" that serves as the connection of suppliers to the factory, and connects the factory to customers as well; it disrupts economies of scale so as to allow the involvement of new competitors, and it improves flexibility and speed.
iii. Distributed innovation makes it possible for crowdsourcing to be utilised in looking for radical solutions to technical challenges in a quicker and cheaper manner compared to traditional R&D.

The overall trends may be summarized as:

- Moving Industry towards energy efficient manufacturing processes
- Rapid manufacturing technology
- Overcoming processing limitations of polymer materials
- Emphasis of precision controls on processing machinery
- Emphasis of multi-skill, multi-discipline personnel

3.7 Environment and Sustainable Development

Companies and countries have shown increasing interest in greenhouse gases, energy, consumer's wastes, and recycling. The focus of current and future global concerns will mainly be on the environment and on sustainable development. The United Nations defines sustainable development as the capacity to meet today's needs without compromising the future generations' ability to meet theirs. Increased efforts to improve sustainability means that each aspect of our lifestyle and all our everyday activities, including plastics, are put under scrutiny.

Thus, we all have to make wise choices by:

- Making "green" decisions based not on perceptions but on science and facts taken from reliable sources
- Using an integrated and holistic life cycle assessment (LCA) to evaluate solutions

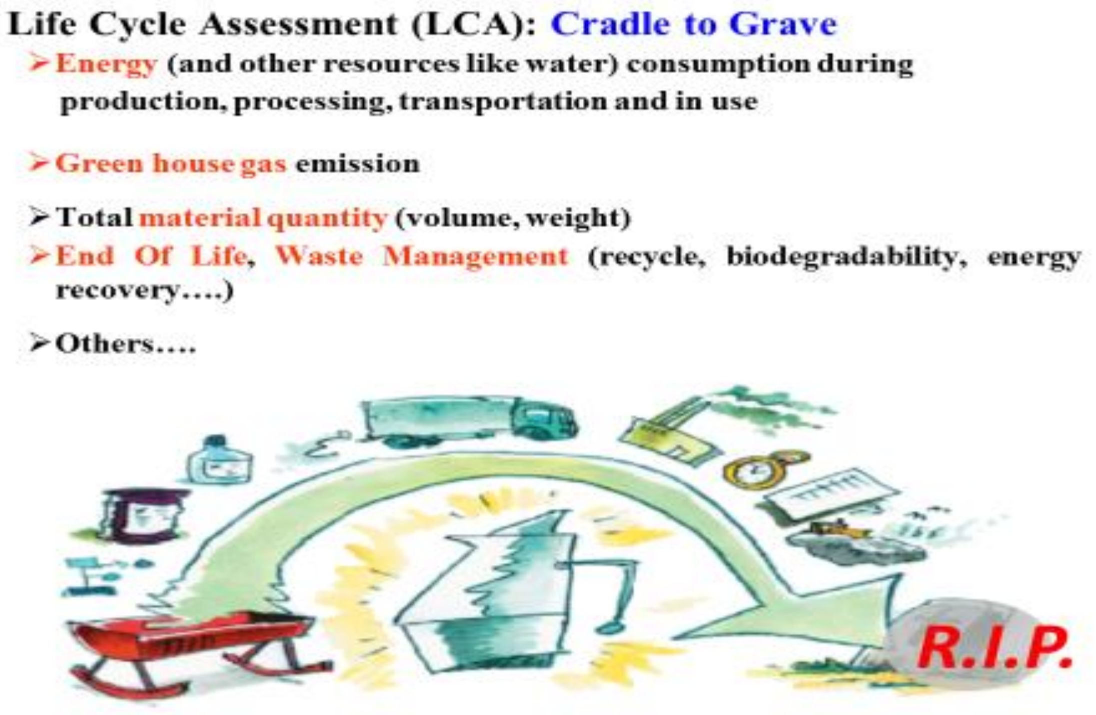

Figure 9: Life Cycle Assessment (LCA): Cradle to Grave (Malaysian Plastic Forum (MPF) 2012)

Plastics and composites are considered lightweight materials that have a vital role in enabling the growth of industries such as automotive, aerospace, electrical and electronics, packaging, and building & construction. For example, plastics have made the newest innovations in sustainable packaging design possible. Generally, plastics allow companies to transport more products while using less packaging material. Packaging made from plastic minimises spoilage and breakage, extends freshness, reduces waste, and saves energy. Moreover, it is now easier to recycle plastic bottles, bags, caps, and containers given the numerous locations and programs across several countries.

However, the ubiquitous uses of plastics in our daily lives have led to many issues. There are many negative perceptions about plastics some of the main ones are as follows:

i. Usage of large amounts of non-renewable crude oil;
ii. Plastics are generally considered non-degradable since it takes them 1,000 years to degrade. Thus, they are often considered bad;
iii. Plastics result into littering and it is often believed that using a different material will benefit the environment.

Figure 10 shows that only 4% of global crude oil production is utilised to produce all the plastic products that we use every day. Despite this information, a lot of people still believe that massive amounts of crude oil are being consumed for this purpose. It should be noted that the largest consumer of oil is the transport industry, using up 45% of the total global crude oil, followed by heat, electricity and energy sector at 42%. This information was taken from an EU Commission report published in 2007.

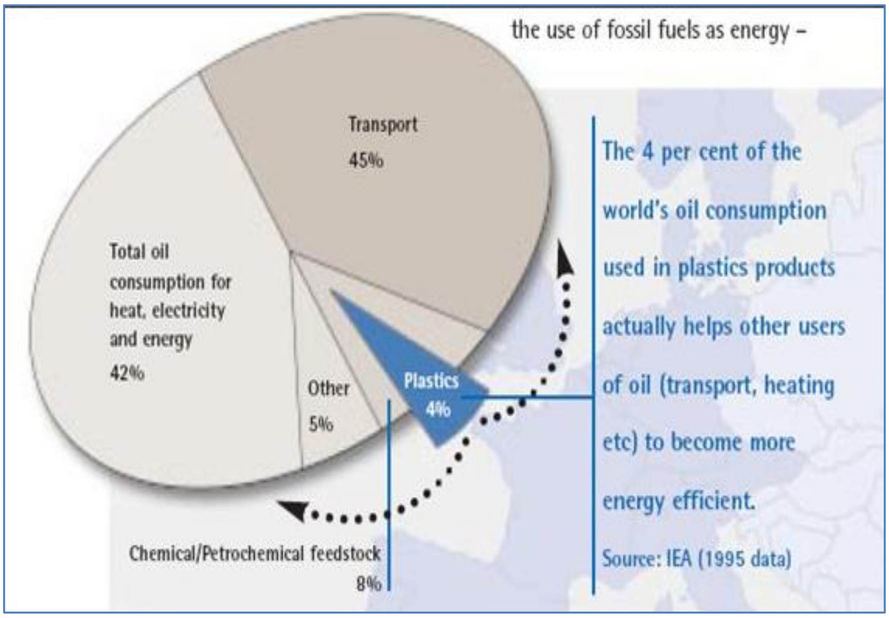

Figure 10: The use of fossil fuels as energy (Spritzer 2011)

Thus, plastics are actually energy efficient and they can even save more resources. In other words, the efficient and effective use of plastic will actually lead to the preservation of fossil fuel resources. Generally, the utilisation of plastics conserves more oil than their manufacture:

i. Automotives:

Western Europe utilises 1.7 million MT of plastics for the automotive parts, produced using 3.25 million MT of oil. The following are the savings achieved from lightweight efficiencies:

- 12 million MT of petrol every year
- 30 million MT reduction of CO_2 emission every year
- End of life energy recovery equal to 1.9 million MT of oil equivalent

Most important is that 10% reduction in weight equals 7% fuel savings.

ii. Aircrafts :

The Airbus A380-800 – fibre composites account for 25% of the material used in the plane. Fuel efficiency is 3.3 litres per person per 100km versus 4.3 litres for the Boeing 747-800, an improvement of 23%. The amount of plastics and composites are increasing in aircrafts. The Boeing 787 Dreamliner comprises of 50% composites. It has wings and fuselage almost exclusively made from composites. The windows are 50% larger giving additional savings in lighting. Meanwhile, the Airbus 350XWB which is being developed consists of 52 % composites (Refer to the Figure 11). Hence, saving weight by using plastics and composites results in protecting the environment and cost savings (Spritzer 2011).

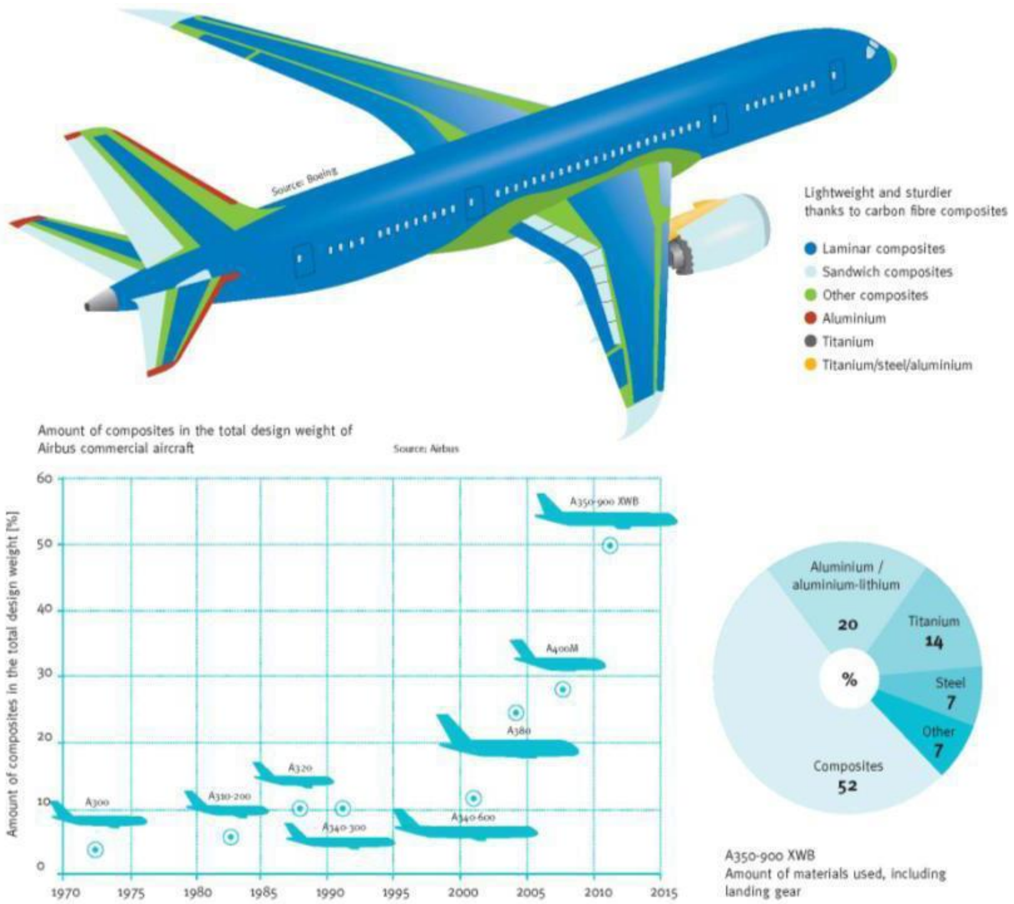

Figure 11: Fibre composites used in the plane (Malaysian Plastic Forum (MPF) 2012)

iii. Food packaging:

Globally, food packaging uses up about 40% of plastics produced. Plastics help reduce food waste, preserve food, and lower packaging weight. Compared to other materials, plastic packaging is significantly more energy efficient. A 1% increase in the efficiency of packaging actually leads to food waste reduction by about 1.6%

In Europe, approximately 50% of food products are packed in plastics, equivalent to only 17% by weight for all packaging. Compared to the 50% food waste in developing countries, their food waste is only about 2–3% (Tampere University, Finland). Without plastics packaging, the following might happen:

- Overall packaging by weight will be higher by 291%
- Manufacturing energy will rise by 108%
- Waste volume will be higher by 158%

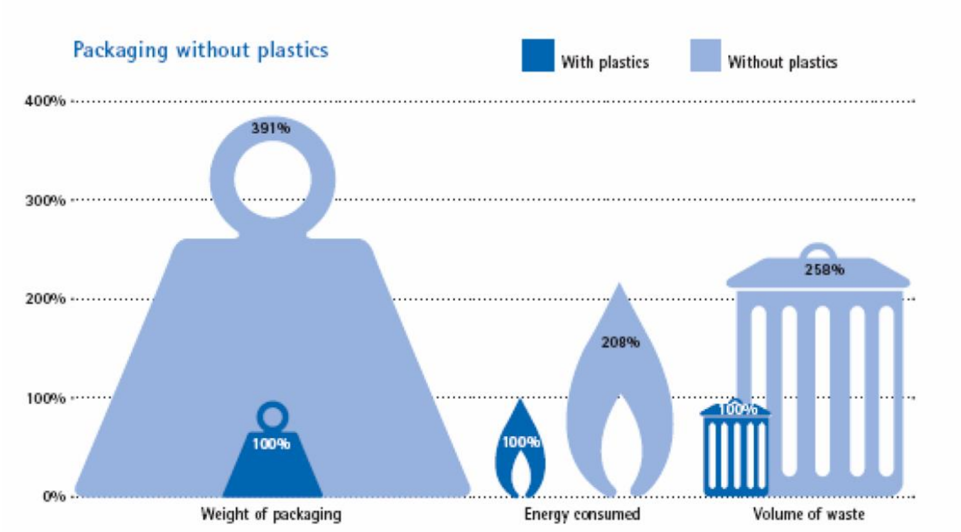

Figure 12: Comparison packaging with and without plastics (Source: Plastic Europe) (Malaysian Plastic Forum (MPF) 2012)

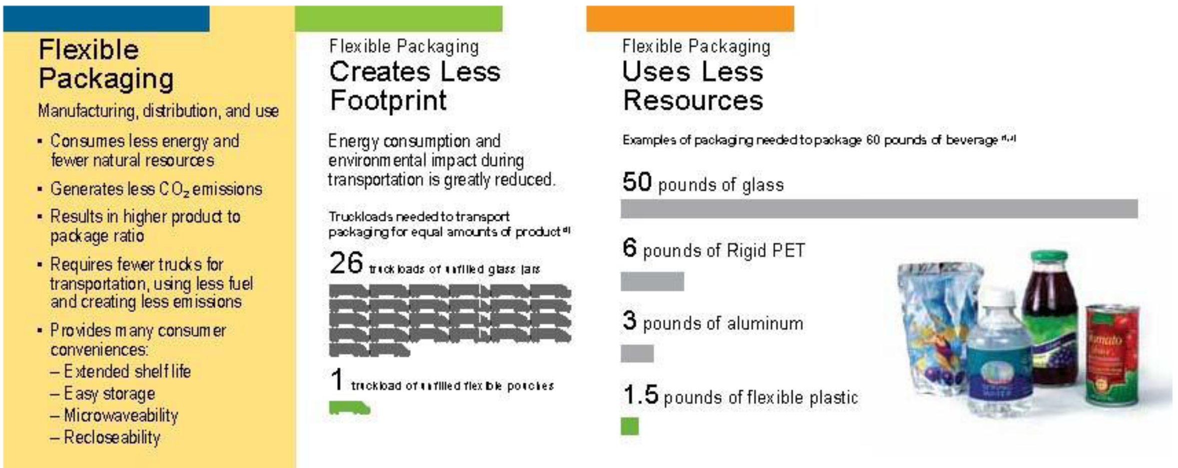

Figure 13: Flexible packaging: Manufacturing, distribution and use (Malaysian Plastic Forum (MPF) 2012)

As clearly observed, plastics' energy efficiency actually helps the world save the quickly diminishing global crude oil reserves. Plastics allow the two main consumers of crude oil (87% - heat, transport, electricity and energy) to become more energy-efficient and in turn reduce the consumption crude oil and avoid further depletion of the crude oil reserve. Thus, it is actually possible to make use of a little amount of crude oil energy to produce plastics and, in turn, conserve a lot of energy by utilising them.

Is it bad??

The following excerpt was taken from the website of the Australian Department of Environment, Water, and Heritage & Arts (DEWHA):

- "The degradable versus conventional plastic bag argument is very complex. Some question whether there is any benefit in using degradable plastic bags if they are just going straight to landfill, as they may not break down in the dry and anaerobic conditions found in most Australian landfills. Alternatively, if they break down they may contribute to generation of methane, which is a potent greenhouse gas"
- "Based on our consultancy report entitled, The Impact of Degradable Plastic Bags in Australia, we can conclude that there might be little benefit if biodegradable plastics are used and subsequently disposed into landfills. This is due to the fact that microorganisms cannot thrive in the dry, oxygen-deprived conditions that are typically common in landfills. Different biodegradable materials, including paper and food, have actually been discovered to be "mummified" and preserved under those conditions. The low oxygen level means that even if the degradable materials degrade, they can still release methane when they break-down. Methane is a very potent greenhouse gas"
- "Plastic bags that are commonly replaced by degradable plastics actually make up a small (by volume) of the waste going into landfill, and most plastics are inert and do not contribute to toxic emissions or leaching."

Thus, as depicted below (see Figure 14), biodegradable bags and food still cannot undergo decomposition in today's modern landfills. Moreover, even if they degrade, they are still expected to give off very detrimental methane (CH_4) gas, which is 22 times more toxic as a greenhouse gas (GHG).

Figure 14: Artefact excavated by an I.S. 318 student on 28 October 1999 at Brooklyn's Dead Horse Bay (Malaysian Plastic Forum (MPF) 2012)

Plastics are made out of crude oil, which in turn was obtained from a hole in the ground. Plastic could have the tendency to stay inert when disposed in a modern landfill. However, being inert in the ground is still a form of carbon-capture and storage (carbon sequestration). In turn, this lowers the amount of harmful greenhouse gases (GHG) that are present in the atmosphere. However, it is still better to recycle it instead of sending it to the landfill.

Plastics often perform well compared to other materials in terms of air and greenhouse gas emissions, energy and water use, and solid waste. A 2014 study entitled "Impact of Plastics Packaging on Life Cycle Energy Consumption & Greenhouse Gas Emissions in the United States and Canada" (plastics.americanchemistry.com) has revealed that the use of the six main types of plastic packaging has aided in the significant reduction of greenhouse gas emissions and energy use compared to packaging alternatives that are produced using other materials.

Also biodegradable plastics have issues such as Food vs. Bio Plastics (since most are derived from food crops), cost performance, economies of scale and low carbon footprint of conventional plastics bags vs. biodegradable ones based on Life Cycle Assessment –LCA as per the above study and one by The Environment Agency of UK report SC030148, LCA of

Carrier Bags, published in media in 2011(See **Error! Reference source not found.**, Figure 16 and Figure 17)

Figure 15: Document overview of the life cycle analysis on carrier bags conducted by the Environmental Agency (Malaysian Plastic Forum (MPF) 2012)

GLOBAL WARMING POTENTIAL PER BAG

Total Global Warming Potential shown in KG/CO2 equivalency

euro packaging

BAG TYPE	AVERAGE BAG WEIGHT (g)	CO2 EQUIVALENT PER 1KG OF BAGS	CO2 EQUIVALENT PER BAG (KG)
HDPE Vest Carrier	8.12	1.578	0.0128
Oxo Degradable Vest Carrier	8.27	1.750	0.0145
Starch Based Biodegradable Vest	16.49	4.184	0.0690
Paper Bag	55.2	5.525	0.305
LDPE 'Bag for Life'	34.94	6.924	0.242
Non Woven PP Bag	115.83	21.510	2.491
Woven PP Bag	120	23.088	2.770
Cotton Bag	183.11	271.533	49.720
Jute Bag	190	273.111	51.891

DATA SOURCE: LIFE CYCLE ASSESSMENT OF SUPERMARKET CARRIER BAGS REPORT SC030148, PUBLISHED BY THE ENVIRONMENT AGENCY

Figure 16: Global warming potential per bag (Malaysian Plastic Forum (MPF) 2012)

EXECUTIVE SUMMARY

euro packaging

The HDPE vest carrier is the

MOST ENVIRONMENTALLY EFFICIENT with the LOWEST CARBON FOOTPRINT

IF THESE BAGS WERE BANNED…

IT WOULD BE WORSE FOR THE ENVIRONMENT

Figure 17: Executive summary of LCA (Malaysian Plastic Forum (MPF) 2012)

The following is another excerpt from the LCA report mentioned above:

A report from the British Environment Agency has stated that single-use polyethylene grocery bags actually leave lower carbon footprints compared to alternative reusable or paper bags. However, an important consideration is the amount of times that the bags are reused. The report states that in order to be equal to an HDPE bag that is utilised once:

- A paper bag has to be reused at least three times;
- A low density polyethylene "bag-for-life" has to be reused at least four times;
- A non-woven polypropylene bag has to be reused at least 11 times;
- A cotton bag needs to be reused at least 131 times.

For example, if the HDPE bag is reused as a trash bag, the numbers rise:
Paper bag will now need to be reused seven times;

- The LDPE bag has to be reused nine times;
- The PP bag has to be reused 26 times
- The cotton bag has to be reused 327 times.

Lastly, the perception on "Plastics is the cause of littering and switching to other materials is good for the environment". Litter is a disgusting blight on our landscape, caused primarily by irresponsible behaviour. Hence, it is not the fault of the packaging, container, bottles or materials such as plastics, paper, glass, etc. The key is switching people's behaviour not the materials.

Litter disfigures our landscape, mainly because people behave irresponsibly.

Littering is product of a behavioural problem

"We made a mistake and plastics are not the culprit. It is the behaviour of the many and not the bag that pollutes."

(Michel-Edouard Leclerc, an initial promoter of the ban on plastic bags in France)

In Malaysia, in order to address the root causes, the Malaysia Plastics Manufacturers Association (MPMA) officially launched the Public Education and Awareness Campaign against Littering called "Don't Be a Litterbrug" on 23 June, 2012 (Figure 18). It has been very well received and now have been expanded to include programs like 3R's (Reduce, Reuse, Recycle) and Litter-Free festivals such as for Thaipusam and Ramadhan.

Figure 18: Official launch of "Don't be a litterbug" campaign by MPMA (MPMA 2013)

Keep America Beautiful (KAB), USA's largest volunteer-based community organisation for action and education, has gained real progress in dealing with litter: In a 2009 report, KAB has stated that overall litter was lower by 61% since 1969.

- **Marine Litter Issue**

This has been a hot topic especially in the past decade. Too often litter makes its way onto beaches and into rivers and oceans. The marine litter then accumulates in the ocean gyres - large systems of circular ocean currents with the famous being the North Pacific Gyre (see Figure 19) , most of it (about 80%) is from land litter.

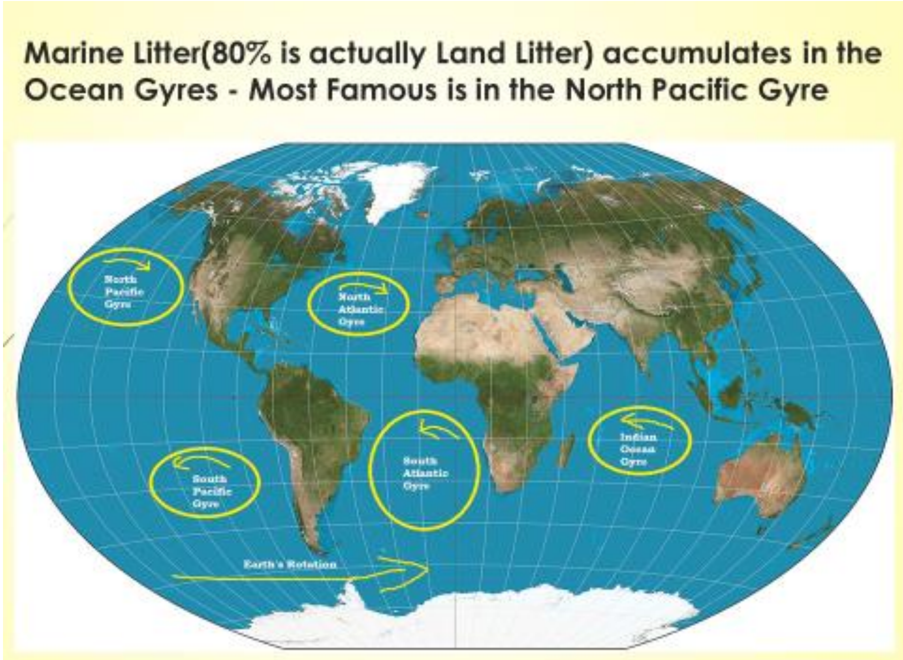

Figure 19: Marine Litter accumulates in the ocean gyre

However, if no serious action is taken in the next few years and "if business as usual" attitude continues with regards to marine litter, we may face with a critical situation by 2050 – more plastics than fish in the oceans? (See Figure 20)

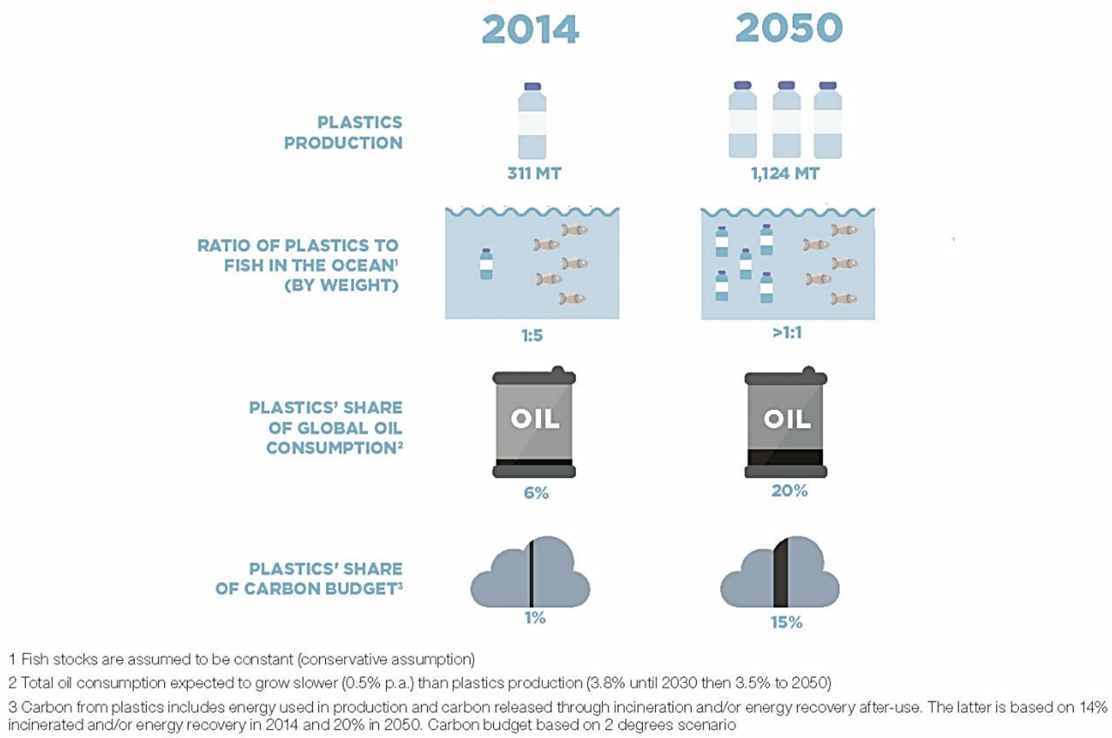

Figure 20: Predictions about plastics volume growth, externalities and oil consumption under a business-as-usual scenario

Marine litter consists of different materials and products. However, relatively lightweight plastics will often float, making them more visible compared to other types of marine debris. They comprise mainly of microplastics (ranging from > 1mm to micrometers). It is important to note that it not only from packaging but also from cosmetics (microbeads), clothing (microfibres), and industrial processes (scrubbers, wear & tear of tyres, paints, etc.) as per the

Figure 21.

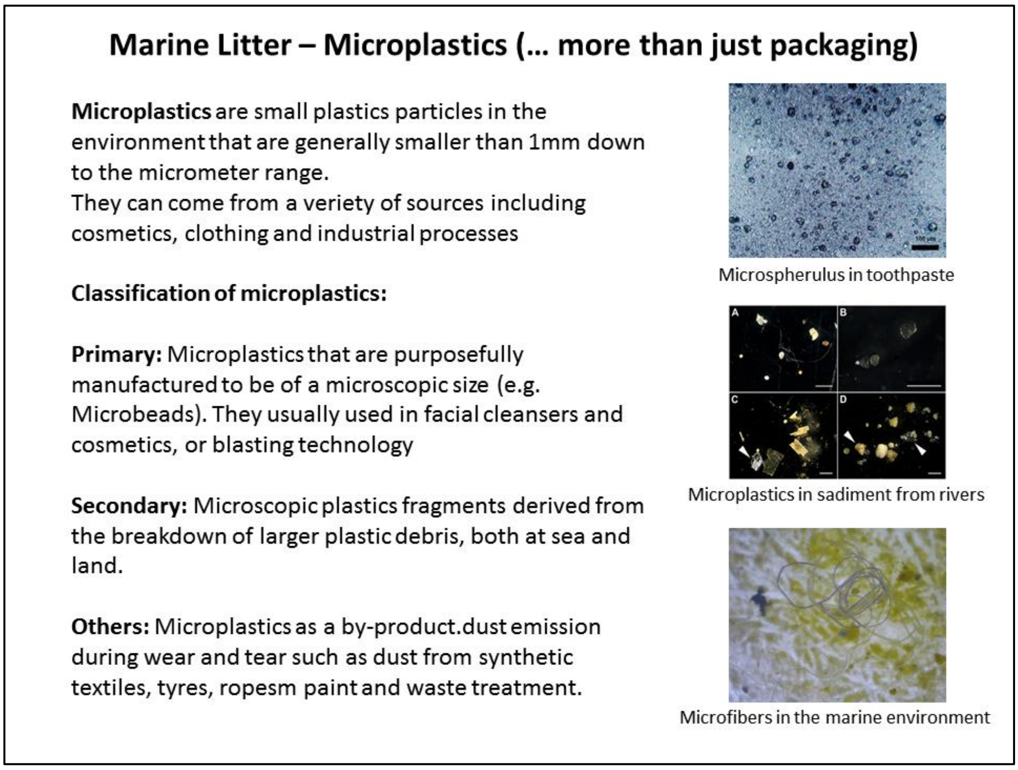

Figure 21: Marine litter – Microplastics (..more than just packaging) (UNEP 2015)

However, photographs of the ocean floor have revealed other problems like cans, bottles, marine equipment, and other refuse. According to the United Nations Environmental Program (UNEP), 70% of marine debris actually ends up sinking to the ocean floor. Thus, for several decades, significant efforts have been focussed on degradable plastics especially for packaging. This was perceived as a key solution for plastics waste management & littering issues.

In a November 2015 report entitled “Biodegradable Plastics Not the Answer to Marine Litter”, the United Nations Environment Protection (UNEP) emphasised the following (See the Figure 22) factors. Polymers, which can be biodegradable on land under favourable conditions, break up much slower when they are in the ocean. The increase in their everyday use will most likely increase marine litter and lead to adverse consequences for marine ecosystems.

The report also quoted some research that suggested that some people are drawn to 'technological solutions' as alternatives to shifting behaviour. For example, tagging a product as biodegradable could be viewed as a technical solution that takes away the individual's responsibility and leads to a reluctance on their part to take action.

Figure 22: Marine litter – degradation not a solution (UNEP 2015)

Since marine litter does not have political or geographic boundaries, solutions must be global and have to involve international partnerships. Solutions should aim to prevent all forms of litter from getting into our oceans and waterways. Hence, a solution with a holistic approach is needed where "prevention is better than cure" prevails. The new plastics circular economy should offer the right answer.

4.0 GLOBAL OUTLOOK

The latest UN projections state that by 2050, the population of the Earth will increase from 7.3 billion to 9.7 billion. In order to continue growing and prospering, the plastics and composite industry has to come up with new strategies that can address different global challenges and satisfy the growing demands from regions of high population growth. The middle class sector is seen as a major consumer of plastics and composites. Moreover, with global population seen to have over 60% of people belonging in this demographic by 2030, there will be a continuous and dramatic growth in the demand for plastics (Saudi 2015).

4.1 Plastics industry

This revolution in the plastics technology is serving as the driving force for intelligent innovations in the electronics, packaging, transportation, medicine, aerospace building and construction, defence, and alternative energy sectors. A new generation of organic plastics is being developed through the synthesis of the molecular attributes and advantages of various natural materials. Among the latest developments are plastics that can heal by themselves; plastics that can use up “destructive” gases and detect toxins; plastics that can conduct electricity and be magnetised and/or miniaturised; and plastics that are heat-resistant and are even capable of stopping speeding bullets (Steve 2014). Overall, given the faster pace of 3D printing innovations and the development of new production procedures, the plastics industry is expected to continue being a strong and steadily evolving sector of the manufacturing industry. The following are just some of the recent trends that are believed to be related to the plastics industry’s global technology outlook:

i. 3D Printing:

In plastics manufacturing, 3D printing has gained more popularity since it allows a manufacturer to produce any object as long as it is in one complete piece and is self-supporting. The objects can be produced in a manner that is quicker and more efficient. It is expected that 3D printing technologies can revolutionise global manufacturing and lessen the industry’s dependence on Chinese imports that are mass manufactured. As 3D printing technology becomes cheaper, it will be able to support cheap and quick prototyping processes, which in turn will help people turn ideas into physical products and tools quickly (Steve 2014).

ii. Recyclable thermoset plastics:

Due to their durability, thermoset plastics are a vital part of our modern world, and are used in everything from mobile phones and circuit boards to the aerospace industry. However, the same characteristics that have made them essential in modern manufacturing also make them impossible to recycle. As a result, most thermoset polymers end up as landfill. Given the ultimate objective of sustainability, there has long been a pressing need for recyclability in thermoset plastics. New classes of thermosetting polymers that are recyclable have been discovered (called polyhexahydrotriazine), or PHTs. It is expected recyclable thermoset polymers to replace unrecyclable thermosets within five years, and to be ubiquitous in newly manufactured goods by 2025. Meanwhile in thermoplastics e.g. PET wastes recycling, current technologies are available to make the recyclates from post-consumer wastes safe for food contact applications (Meyerson 2015).

4.2 Composite Industry

Despite composite materials being successful in breaking into various market segments, the consumers' increasing needs make it necessary to still have continuous innovations. Industry leaders have developed new fibres, resins, nano-materials, compounds, bioplastics, etc. Technology suppliers have also started to develop new technologies to promote low energy consumption, rapid production, and less wastage of raw materials. The industry is now being penetrated by the lightweighting and cost reduction of materials. Mega trends in innovation also influence individual sectors of the composites industry, such as resins, composites technology, fibres, and end-use applications:

i. **Fibre innovations:**

Future development of low-cost carbon fibres for applications in the wind energy, automotive, and industrial sectors is seen to experience significant innovations. Industries are also considering low-cost alternative precursors like lignin, textile polyacrylonitrile (PAN), and polyolefin. Moreover, lowering energy cost is another focus. Within the GFRP market, higher mechanical and chemical requirements are being met by suppliers by developing high-performance glass fibres.

ii. **Resin innovations:**

Additional new resin product launches will focus on mass volume applications having shorter cure times. They have developed epoxy resin systems for compression moulding and high pressure resin transfer moulding (HP-RTM) that have shorter cycle times. The wind energy segment is developing resins that have optimised gel time for long wind blades.

iii. **Technology innovations:**

Significant mega trends in innovation for composite technologies are focusing on achieving quicker cycle times lower capital, better product quality, and lower processing costs. One major technology challenge is achieving targeted one- to two-minute cycle times that can be applied for mass volume automotive applications. With the development of technologies such as compression moulding, HP-RTM, pressure press and forged composites, and carbon fibre reinforced thermoplastics, this goal can be addressed in the near future.

iv. **Application innovations:**

The composites industry is developing enhanced applications in almost every segment. For example, in the automotive industry, automakers have started to integrate carbon composites in mass volume cars in order to produce lighter vehicles. Furthermore, in the wind energy sector, there is a growing trend that is pushing the development of one-piece and modular wind blade technologies (Mazumdar 2015).

v. **Nano-technology:**

Nanotechnology is another exciting technological development that can make potential significant contributions to the future of plastics. By using nanotechnology, special nano composites (polymer metal fibre, carbon nanotubes, graphene, nanofibres, nanoplatelet, etc.) that will be more resistant to heat, dent, and scratch can be developed. Yet, the thermoplastic resins that are utilised in the production of plastics can still be processed using the same equipment that is currently being utilised for resin processing. The aerospace industry has also experienced several innovation mega trends. Hence, it is expected that more applications for carbon composites and nano composites will emerge.

4.3 Current and future applications of plastics and composites

Some examples of important current and future applications arising from the plastics and composite development include the following sectors:

i. Transportation:

   Similar to the auto sector, air transportation is also going through a materials transformation with heavier materials being replaced by new polymer composites. New polymer composites in airplanes can actually significantly reduce fuel consumption, leading to less pollution and cheaper fares.

ii. Medical:

   Medical devices are also being developed. An example of this is the creation of a replacement hand that is produced using high-strength plastics. The artificial hand can actually look and work like a real human hand. It uses the electrical signals produced by the muscles of the patient's remaining limb to open and close the fingers.

iii. Electronics:

   Laminar electronics are considered the new wave of the future. Compared to ordinary screens and cathode rays, LCD monitors utilise 65% less power. It is expected that in the near future, rolls of plastic (power) films that can transform light to electricity can be commercially manufactured.

iv. Aerospace:

   Ablative plastics are utilised in the U.S. space shuttles as a heat shield that prevents the shuttle from incineration as it enters the earth's atmosphere again. The heat is absorbed by the plastics and the plastics then burn off. The Canadarm2 is produced using a lightweight carbon fibre thermoplastic composite. This composite was chosen because of its stiffness, strength, and capacity to withstand large amounts of radiation.

v. Defence:

A new class of vessels for stealth naval defence is being produced using carbon fibre that is integrated with plastic that can help avoid detection – whether it is radar, visual, sonar, or infrared. Since they are less dependent on traditional materials and are instead built with a construction of carbon composite sandwich of plastic materials (glass, Kevlar, PVC), the hull weight of these ships is lowered by as much as 30%.

vi. Food packaging:

Intelligent food packaging helps extend the lifetime of food and protect our health and. Technology developments have led to the creation of diagnostic plastics that can actually sense bacterial presence. Plastic can increase the shelf-life of food because it absorbs ethylene gas, a plant hormone that initiates the process of senescence and decay (Canadian Plastics Industry Association 2015).

4.4 Global business outlook

Since 1950, the global plastics industry has experienced an average annual growth of 9%. The total production of plastics has grown by approximately 500 % in the past 30 years alone. From just 1.5 million tons in 1950, the global plastics production has experienced tremendous increase and has grown to 208 million tons in 2014. By 2015, the demand for global plastics is seen to increase by 5 % annually due to global megatrends that include energy demand, urbanisation, new technology developments, and climate change. The different megatrends that direct growth have a close relationship with industry sectors such as energy efficiency, construction, and housing areas. Moreover, plastics are playing an increasingly important role in these areas. The global plastics market is forecast to reach USD650 billion by 2020. Moreover, assuming a steady growth, the global plastics consumption could reach USD3 trillion by 2050 (Germany Trade & Invest 2015).

Increasing disposable incomes, population growth, changing lifestyles, and urbanisation are expected to direct the demand for the developing plastics market plastic in the coming years. Plastics demand is also a reflection of the downstream industries' growth.The current lower oil prices have impacted economic development resulting in winners and losers. For petrochemicals this will result in falling production costs and changes to industry competitiveness. This scenario has made those based on oil based feedstock such as naptha more competitive (Anz Insight 2012).

The new petrochemical investments are heavily focused on the US Shale gas, Middle East and China. However shifts in feedstocks will create a need for more on-purpose propylene production to meet market needs. China is ramping up chemical production across most sector value chains. For global plastics consumption, polyethylene (PE) types such as HDPE, LLDPE and LDPE are the largest at 81 million tons (39%), followed by polypropylene (PP), including the various PP copolymers, at 56 million tons (27%). Application wise, the top four global markets for plastics are the packaging (40%), building & construction (20%), electrical & electronics (12%) and automotive sectors (7%) (Mbogoro 2013).

Globally, the composites industry is expected to grow by about 4% in 2015. By 2019, the global composites market is expected to experience exceptional good growth and even be valued at approximately USD35 billion. By 2050, the composites market is seen to experience significant growth given the new developments created in different sectors. It could even reach USD285 billion. The improving economic conditions in areas like the US and Europe are seen to drive the market for global composites and lead to strong growth. The composites industry has seen steady growth for three decades, given its rising market penetration in the wind energy, construction, aeronautics and automobile sectors. The Asian region has already come out as the biggest growth area for the composites industry and the global market expects the region to further strengthen its leadership. By 2020, Asia is expected to gain a total market share of about 50% by volume. North America is anticipated to come in second by 2020, with an expected market share of about 29% (Lucintel 2014)**.**

Acmite has stated that in 2013, the carbon fibre market earned global revenues of about USD1.77 billion (Witten & Thomas 2014). Between 2011 and 2013, all the major carbon fibre manufacturers have drastically increased their production capacity in order to meet the ever-growing global demand. Moreover, countries like South Korea, Russia, and India have built new capacity.

In 2012, the global capacity for carbon fibre production was 111,785 tonnes. It is expected to reach 169,300 tonnes by 2020. In 2012, the demand was at 47,220 tonnes and this is expected to increase to 102,460 tonnes by 2020. This over-capacity could actually encourage the maintenance of competitive prices. Overall, the market for global composites market is seen to be equal to 12 million tons every year and is estimated to be USD483.5 billion in value. However, Russia makes up for just 0.3–0.5 percent of the world market as it only produces tens of thousands of tons a year. In order to obtain a larger share of the global composites market, the Russian government created a roadmap intended for sector development in 2013. The plan aims to have Russia produce composite materials equivalent to USD1.9 billion by 2020, with 10 percent of this amount amounting to exported materials.

As of now, the carbon fibre market is being dominated by 10 leading fibre manufacturers. As of 2013, these manufacturers are in control of over 91% of the production capacity. Toray completed acquired Zoltek in March 2014 and has therefore increased its leading position in the market significantly. In Japan, China, and the US, the manufacture of carbon fibres utilises pitch as a raw material (Witten & Thomas 2014). This method's total capacity is equivalent to about 3,400 tonnes per year.

MIDA reported that Nippon Electric Glass (NEG) Company plans to invest RM718 million to increase glass fibre production capacity by 17% in Shah Alam, Selangor. NEG produces about 30% of the global market share. The product is utilised as reinforcement for high performance resin that is used in automotive parts and engineering plastics applications. NEG will take advantage of this increase in capacity to further expand its glass fibre business. About 90% of the products it will produce will be exported to markets in the US, Europe, China, and Republic of Korea (MIDA 2015).

In 2013, the global production of natural fibres was to be at 33 million tons and with a farm value equal to about USD60 billion. The production of natural fibres like flax, hemp, abaca, jute, ramie, kenaf, kapok silk, and sisal amounted to approximately 1.6 million tons and a farm value of approximately USD3 billion. These fibres are generally utilised for insulation materials, speciality pulp & paper, and for bio-composites for use in automotive applications.

The market for natural fibre composites (NFC) is expected to increase at a CAGR of 11% for the 2014–2019 period. The NFC market is mainly driven by the increasing demand for eco-friendly and sustainable products, recyclability, increased penetration of natural fibre composites materials in the automotive industry to create lighter parts and improve fuel efficiency, and encouragement from various governments in the marketing of bio-composite products that can protect the environment and human health. During the forecast period, automotive applications are expected to stay as the largest market in terms of both volume and value. Automakers are automatically motivated to spend premium for green composites. Moreover, they need these green composites to be on par with traditional alternatives in terms of performance, price, and durability. Currently, the European automotive industry uses up about 30,000 tonnes of natural fibres. The natural fibre composites market is also being driven by rising demand from electrical/electronic industries and building and construction sectors.

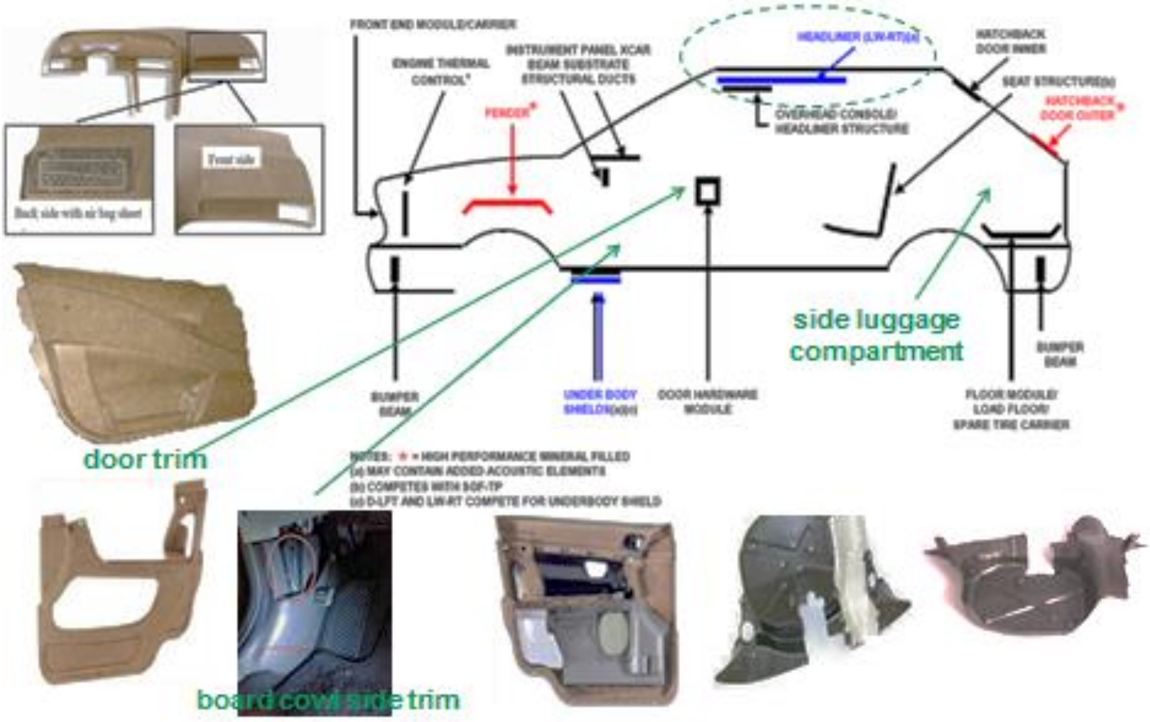

Figure 23: Natural fibre used in various automotive applications

Recently, the Biofore Concept Car was developed by the forest and biomaterials supplier of Finland, UPM, and the Helsinki Metropolia University of Applied Sciences. The goal was to replace most of the parts that were typically made up of conventional materials and use, safe, high-quality, and durable bio-based composites instead. Different automotive parts like side skirts, front mask, dashboard, and interior and door panels have been produced with the use of PP and HDPE that were reinforced with cellulose fibre via extrusion, injection moulding, and thermoforming techniques. Given its up to 50% content of renewable raw material, the car is lighter by about 150kg compared to its equivalents, leading to lower fuel consumption (FlexForm Technologies 2013).

Figure 24: Biofore concept car (FlexForm Technologies 2013)

By 2015, the National Kenaf and Tobacco Board (LKTN) aims to have 5,000ha of land used for kenaf cultivation. This is in line with the National Commodity Policy that aims to turn the versatile plant into an important national economy contributor by 2020. NKTB has identified the following factors which are deemed critical for successful development of kenaf industry:

i. All stakeholders in the industry need to understand their roles and responsibilities and fulfill them through working in close cooperation with each other.
ii. Achieving the economies of scale is necessary for a commodity crop industry to be sustainable on a commercial basis.
iii. The presence of thriving downstream industries is needed to provide healthy and sustainable demand for kenaf raw materials.
iv. Consistent and coordinated efforts in R&D by stakeholders is vital for the industry as a whole to stay abreast of the competition
v. Standardized quality control and measurement system is essential for sustainable long term development of kenaf as a commodity crop
vi. Management of risks to the industry is to be undertaken at all levels to prepare for the unexpected and to mitigate potential risks
vii. Sufficient human and financial resources are needed to execute upstream, midstream and downstream activities.

Those factors are pivotal in transforming the domestic kenaf industry from a crop cottage industry that is reliant on subsidies, low-yielding and uncoordinated to an emerging commodity crop which is vibrant, self-sustaining, and industry-driven and focused on high-value products.

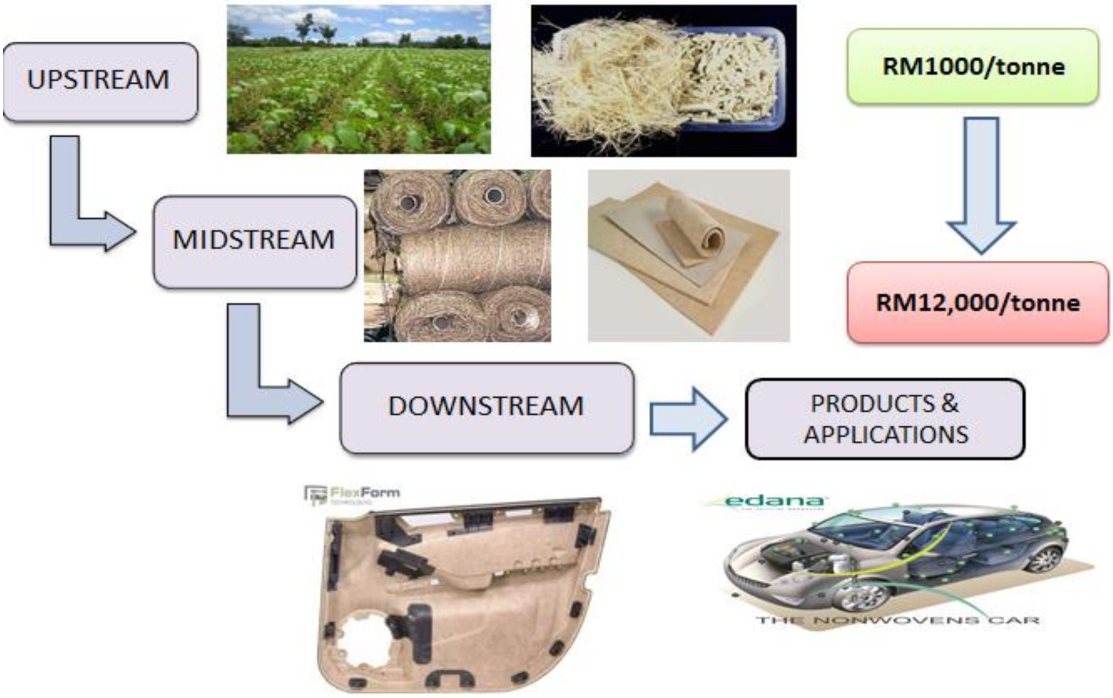

Figure 25: Value Chain: Upstream, Midstream and downstream activities

By 2017, the kenaf industry is expected to be industry-driven and self-sustaining with commercial-scale farms. By 2020, it is expected to grow into a vibrant, modern and competitive industry that is focused on high-value products that is able to contribute positively to the national economy. Subsequently, this will help position the industry towards becoming the nation's third commodity crop after oil palm and rubber. After 2025, it is envisioned that kenaf industry can take the lead in the push for environmentally-friendly products.

In 2013, experts projected the demand for wood-plastic composites (WPC) to increase by 9% per year until it reaches USD5 billion. These gains will be directed by the continuous consumer acceptance of these products as alternatives for more traditional materials like wood.

Figure 26: Extruded WPC products

Composite and plastic lumber will witness increasing demands because of their long lifespans, resistance to degradation caused by exposure to the elements and insect attack, minimal maintenance requirements, and capacity to be cut and handled like natural wood. Moreover, the increase in demand will be driven further by the growing viewpoint that these materials are environmentally friendly products since they incorporate recycled materials (Wallstreet-online 2015).

Figure 27: WPC decking alternative for solid wood.

It is estimated that by 2016 it will be nearly at 4.6 mil metric tons and will continue to increase at a robust CAGR amounting to 13.8%, based on BCC Research. The building products market is forecast to have the highest growth, with a CAGR of about 12.4% for the 5-year period corresponding to the years 2011 to 2016. In 2011, the sector grew to about 1.7 mil metric tons and it is expected to increase to 3.2 mil metric tons in 2016. In 2011, the market for automotive applications was forecast to be at about 350,000 metric tons and this is expected to rise at a 17.1% CAGR, equivalent to about 8,00,000 metric tons (Smartech Global Solutions 2014).

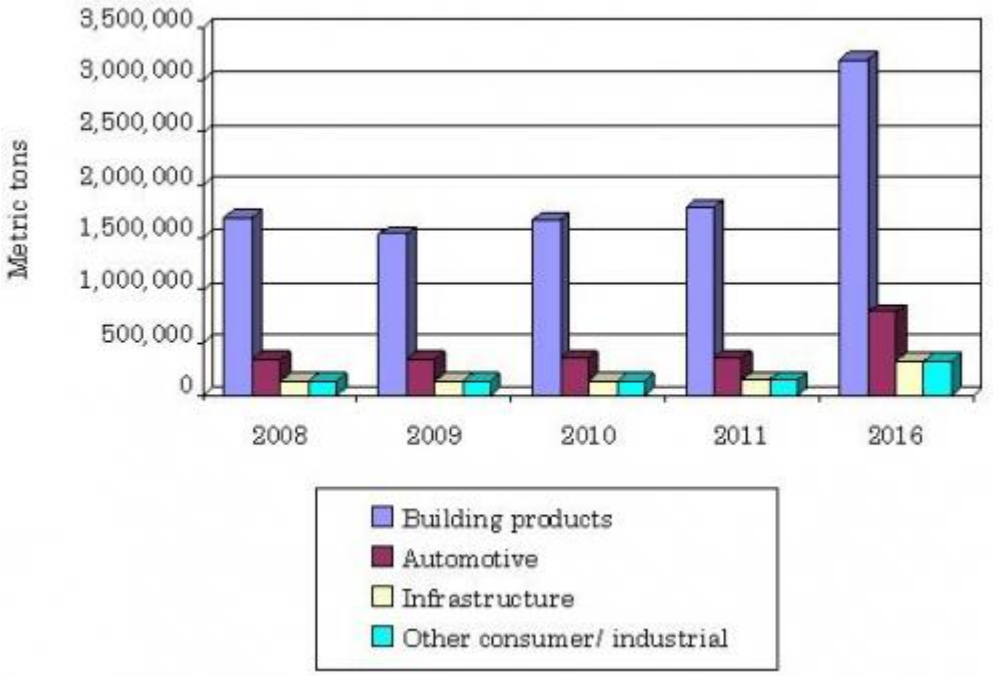

Figure 28: Global market for applications of wood-plastic composites (WPCs)

WPC produced in Europe in 2012, the decking is leading with 67% (mainly extrusion), followed by automotive interior components with 23% (mainly compression moulding, sheet extrusion and thermoforming). Consumer goods and furniture are expected to increase their market share in the near future.

By 2050, it is envisaged that the current Malaysian top 3 key market segments for plastics industry i.e. packaging (45%), electrical & electronics (E&E) (26%) and automotive (10%) will relatively remain the same. Similarly for the local composites industry, the top 3 key markets segments i.e. aerospace, automotive and building & construction (B&C) are expected to be maintained. Overall, the growths of the two aforementioned industries' top 3 key segments are also expected to be positive, although by 2050 it should be "Smart Packaging", "Smart E&E", "Smart Automotive or Cars" and Smart "B&C" through the convergence of technology (a Megatrend).

By 2050, we expect a greater convergence of technologies in the production of "Smart Materials", based on plastics & composites. This convergence includes use of "Smart Technologies" such as nanotechnology (for e.g. graphene for barrier properties, super strength, high conductivity inks) and E&E technology (for e.g. plastics transistors with printed circuits using graphene inks, flexible plastics photovoltaic, new generation batteries) to produce “Smart Packaging”, “Smart Consumer Electronics”, “E&E”, “Smart Cars”, “ Smart Buildings” and etc. These are some of the key components of creating “Smart Industries” targeting “Smart Applications” for “Smart Communities”. They will address the aforementioned relevant Megatrends such as Resource Scarcity, New Patterns of Mobility and Urbanization.

We also expect to find Malaysia by 2050, despite a much larger population at @ 43 million, to remain a net exporter of plastics and composite products. The projected main market will be mainly in ASEAN and Asia-Pacific region instead of the EU, USA or Japan. Generally, we expect that by 2050, the “smart” industries above which utilise plastics and composites will achieve sustainability through the following:

i. Ability or adaptability to various regulatory frameworks (Health, Safety, Environment)
ii. 3Rs (Reduce, Reuse, Recycle or Recover)
iii. World Class Waste Management Culture & Source Reduction
iv. Environmental regulations – increased fuel efficiency, reduced VOC, emissions
ix. Increased awareness of water shortage and global warming issues
x. Thinking (Cradle to Grave or Cradle) and Life Cycle Assessment(LCA) savings in water, energy, carbon footprint, and waste disposal and management
xi. Circular Economy (Wealth out of wastes WOOW, W2W, Waste2Energy)

4.5 Issues and Challenges

The issues and challenges identified in this interim report were mainly the outcome from our 1st Sectoral Stakeholder Consultation Workshop held on 3rd June 2015. Several tools were used for the gap, expected challenges and fore sighting exercises which, among others, included brainstorming, back casting and futures wheel. The outcomes of the 1st Consultation Workshop are summarized in Table 1. The next steps include, if needed, plans to use several tools for the strategic fit, mapping and further gap analysis exercises of the above data. These include fore sighting, SWOT, Six Sigma methodology and benchmarking with relevant peers reports from the other sectors.

Table 1: Issue and Challenges

Identified Focus Area	Identify Gaps (Issues)	Expected Challenges
1) Trends for advanced materials	- Market readiness - Small local demands - Lack of local raw materials – must be imported from other countries (restricted to local rules & regulations - Lack of continuous supply - Lack of innovation	- Raw materials monopolised by international main players - Economy of sales for the local producers (enough local or regional demand) - Cost effectiveness of these advanced materials - Ensuring self-sufficiency in local raw materials & its continued supply
2) Trends for advanced manufacturing	- Short of skilled worker - Labour intensive - Long cycle times - No readily available standard - Lack of automatic rapid prototyping - Lack of customization & specialization	- Current manufacturing & processing culture or manual outdated - Lack of skill workers - Need to develop (including retraining) new skill sets - Mass customization & specialization manufacturing (+/-) - Speed to market effectiveness of advanced manufacturing to produced advanced materials - Cost effectiveness of new technologies
3) New product development	- Lack of confidence in local talent & product - Shortage of indigenous product - Lack of MS standard - Lack NPD blueprint or roadmap - Integrated innovation, R&D cultured underdeveloped	- Lack of confidence with local talent & products - Effective MS & ISO standard - Effective markets & business driven R&D - Government incentives for R&D - Need to develop world class workforce with new skill set, tool and innovation culture - World class NPD blueprint and roadmap
4) Technology environment and sustainable development	- Need more cost effective technology - Non-recyclable materials - Need more sustainable materials (synthetic or natural) - Lack of waste management and 3R awareness - Lack of sustainable policies for home, transport, consumer goods, packaging and E&E industries	- Reediness to sustainable materials to be adopted by the industries - Price of these sustainable materials & technology - Free trade policies (low carbon footprint/trading no 'green washing' - Practicing and enforcing these sustainability or 'green' policies - Wealth out of waste (WOW) , recovery or energy from waste program fully realized

Architects are not particularly well informed about the usage of composite materials. It has been pointed out that both consumers and legislators must be made aware of the advantages of utilising composites in place of aluminium, steel, and wooden materials. Raw materials are mainly imported for manufacturing at a lower scale in Malaysia; output prices can be high as a consequence. As for industrial potentials, economies of scale are required for manufacturers to stay viable. Owing to the bulkiness of these end-product types, GFRP products need to be assembled to fit regular 40-foot container sizes for those to be shipped overseas. Design and manufacturing planning therefore has such parametric considerations to follow, for Southeast Asian manufacturers must factor shipping expenditures to more profitable markets in Europe, Australia, the US and the Gulf nations.

Worldwide market access will be required to achieve economic and manufacturing scales that work to maintain lower price structures. Other aspects that determine industrial potential comprise continued innovations, usage of newer materials, and labour proficiency enhancements. To stay viable, ASEAN manufacturers have to achieve a balance between pricing and quality considerations, which changes constantly as a result of the changing costs of raw material inputs and machineries, most of which are imported from Europe and the USA and farther countries such as China, Japan, and Korea.

The realisation of minimum wages (MW) led to 30–40% raises in general wages, which mostly went to the foreign workforce. The influence of expenditures largely depends on the type of manufacturing, organisational sizes, and the reliance on foreign labour. Globalised access to markets will be required to achieve economic and manufacturing scales that work to retain lower prices. The issue on the shortage of workers both skilled and unskilled has to be addressed. Innovation skill for design and product development within composites industry is still low in Malaysia. Skilled manpower is not readily available since only few academia offer composites courses. High and increased dependency on foreign workers had fulfilled the low skilled job opportunity created by the industries for local workers.

Plastic resins is the major cost component, amounting up to 80% of total manufacturing cost (depending on process and extent of value-add activity). Profit/ (Loss) = Revenue – Cost. The industry faced high cost of resins, particularly when there was a spike from 2004, compared to the lows in the earlier years. The reach into global markets will be needed to attain economies of scale and production volume to keep prices low.

The United Nations Environmental Program (UNEP) has reported that 22–43% of plastic and composite materials utilised globally are later discarded in landfill arrangements. Such materials are put to waste while occupying needed space and blighting communal areas (Unep 2014). The recovery of plastic and composite materials from by-product wastes for recycling and power generation via incineration processes may potentially minimise these difficulties.All the stakeholders should increase their participation in anti-litter and plastics waste management to move plastics wastes toward a recycling or recovery supply chain or circular economy i.e. Wealth out of Waste (WOW) or Waste to Wealth (W2W). Governments and regulators must provide the necessary “Carrots” & Sticks”. Some waste of composites manufacturing, such as offcuts, are potentially usable by the aerospace industry, but certain studies have to be conducted before any real product could be produced using this offcuts. Carbon from scarp composites aerospace components and retired aircraft can be extracted and will not be suitable for aerospace use but would be very advantageous to be used in other area such as automotive. The potential of sustainable bio-composites as alternative materials to replace foreign imported raw materials such as glass fibres need to be explored. The main usage would be for non-structural or semi structural application.

4.6 Future Scenario

It can be anticipated that Kodak’s situation will apply to numerous industrial sectors in the following decades, which would not be obvious to many. In 1998, most observers did not foresee the demise of picture taking using paper-based films. The first digital models featured rudimentary 10,000-pixel resolutions, but successive evolutions pursued Moore's law. As with accelerating technological advances, following early frustrations, the technologies eventually matured, surpassing and superseding film-based technologies within a decade. We anticipate that this process may now occur with artificial intelligences, healthcare, self-guided and electric-powered autos, education, 3D-print fabrication, agriculture, and unskilled employment.

Among the more brilliant insight methods is scenario building, which is used to stimulate discussions about futuristic prospects as well as outline the strengths and weaknesses of current developmental approaches. We should always remember that scenarios are in fact situational narratives about prospects and not forecasting techniques. The aim is to draw insight about futuristic potentials and not to predict any particular ‘future’.

Notwithstanding their limits, scenarios are highly valued, for they can deliver a particularly futuristic message even as others learn from each scenario’s narrative. As well, this stimulates futuristic thinking and stirs rational experimentation, encouraging discourse on prospects that may result in better decision-making.

Such situations commonly overstate current progress in order to better perceive policy or innovation trends with greater clarity. Scenario cases should instead be viewed as intellectual experimentation that assists researchers in drawing inferences from premised evidence, i.e. “What ifs?” or “If this goes on, what disruption occurs?”, and so on. Conjectures that contest commonly held beliefs could help stimulate more open-minded, “out-of-the-box” reasoning.

Negative scenarios that define adverse prospects are equally useful in that significant conclusions can be derived as well to inform succeeding decisions. Such situations blend both favourable and unfavourable factors, transparently rendering the differing expectations, desires, and beliefs of those engaged in futuristic discourse. Each participant’s viewpoint determines whether a scenario is favourable or not, or very probable else impractical.

4.6.1 Smart Home Scenario

In 2050, people will be housed in smart housing which are built from self-healing materials such that house repairing will a thing of the past. The houses will be equipped with smart sensors that optimize lighting and climate control, energy efficient and with self-generated energy capability. The sensors will include bio sensors for authentication of house occupants for security and detect emergency situations (Tso 2012).

Figure 29: Portable and floatable smart house

The house will be portable and floatable and survivable in case of occurrence of natural disasters such as flood and earthquake (see Figure 29). Light weight, strong and fire proof composites materials will have been developed to mass housing.

It is possible to imagine futuristic residences that are sufficiently intelligent to discriminate between family members and various guests, via adaptation to personal needs in accordance with biometric information such as fingerprint, bodily temperature, and even pulse rate data. In one situation, while a person walks around his home, tiny devices on his wrist identify him by pattern-matching his particular heartbeat. This would enable such smart controls to automatically adapt temperature, lighting, and ambient music levels according to individual preferences, based on pre-existing configuration profiles (Tso 2012).

Future home owner will have smart home technology that can trash and treat other wastes (from the toilet) which will be able to be converted into energy or at the least, harmless to him and the environment. In the bedrooms, beds make/change sheets by themselves upon sensing the user have left the bed for more than 5 minutes.

4.6.2 Smart Clothing Scenario

What a smart clothing it will be when it has the ability to convert sweats to sweet smelling musk; from perspiration it results in great inspiration; with self-cleaning and self-ironing capability. It would be nice to have clothes that can remind us about time and date and serve as alarm clock to forcefully wake us up in time for critical appointments. Smart clothes refer to materials that could monitor surrounding temperatures, UV radiation, allergens and pollution. Particularly benefitting wears who are asthmatics, pregnant, children and elderly. Clothing will be recycled while renewable energy resources are developed. Intelligent clothing can supervise healthcare regimes, inform staff, and call for emergency responders when needed.

Smart pyjamas monitor cardiac activities and maintain body temperature and also soothing children and monitor their sleep. This monitoring may help to uncover sleep troubles such as sleep apnea that can lead to strokes and death. Smart garment can detect respiration patterns, body movements and snores that may be symptoms to specific sleep troubles. It is foreseen that in the near future, smart pyjamas also have dedicated algorithms to detect potential troubles. Clothes can be intelligently networked, altering colours and shapes in accordance with localised pollution monitoring. The contextual awareness of such futuristic clothes may be reactive, estimating the wearer's carbon footprint and consequently instilling a religious need for behavioural modification and environmental stewardship.

Some Smart clothes can massage wearers, diffuse relaxing smells and produce soothing music so as to relieve stress and improve quality of life and help fight against depression. Intelligent clothing can offer protective functions for the greater safety of its user. During emergencies, site imagery and locational data can be transmitted by intelligent modules to trusted persons or emergency responders, once physiological fear responses are detected. Such might even have capabilities for incapacitating attackers using electric shocks, marking them with permanent chemical marker compounds. Electricity generation - which is also useful to charge smart phone and devices, can come from polymer based body thermal batteries incorporated in the smart clothing (See Figure 30).

Figure 30: Fashion forward: Hi-tech clothing

Clothes of the future can provide safety against natural disasters. For examples, they can inflate automatically to absorb shocks due to falls, or drowning if tsunamis occur where they are equipped with reactive floaters. Rescue mission can be expedited when clothes can change colour and illumination and emit distress signals during disasters (Gilsoo Cho 2009).

4.6.3 Smart Transportation Scenario

Autonomously self-guided autos are anticipated to launch by 2017. The initial wave should be commercially competitive for general consumer audiences (see Figure 31). From thereon, the entire transportation sector will be subject to disruption, for consumers may not care to drive their own autos at some point. Self-driving vehicles will eventually be bookable via mobile devices, arriving at the user's location to pick him up and drive him to his favoured destination. Such self-guided vehicles may not have need for parking, and users would likely pay only for the distances they were driven, remaining productive while in transit.

Futuristic consumers may also never need driving licenses nor feel much desire to own and drive vehicles. Cities will be drastically changed, traffic congestion will be a scene of the past because there will be 90-95% less cars in the city. Former parking space can be transformed into beautiful green parks. (Cameron 2013)

Figure 31: Self-driving car by Volvo (Cameron 2013)

Globally, around 1.2 million persons die every year in auto mishaps, with accident rates approaching incidences of one for every 100,000 kilometres. By eliminating human factors, it is anticipated that the widespread introduction of self-driving systems will lead to drops approaching one incident for every 10 million kilometres, preventing a million deaths annually. While conventional auto manufacturers employ developmental strategies by just enhancing auto designs over time with greater comforts and fuel efficiencies, high-technology firms such as Tesla, Google, and Apple are pursuing radical strategies and are assembling computerised wheeled vehicles. As it can be seen that mobile phones eventually phase out the convention line phones, the possibility that by 2050, most conventional car companies become obsolete is quite strong.

By 2020, electric cars will, finally become dominates the road. Cities will enjoy considerably lower noise and air pollution since all cars by then will run on electric. With the advent of super-efficient solar power production, electricity will become incredibly cheap and clean.

Software-based advances will disrupt conventional industrial sectors in the following decades. Uber may just be a software company as the firm does not own vehicle fleets, but it has become the largest taxi firm worldwide. Airbnb has similarly become the largest global hotel firm without having to own much property.

4.6.4 Smart Packaging Scenario

In the future, we can also anticipate futuristic smart packages using inexpensively fabricated plastic microelectronics to autonomously advertise themselves to nearby persons in retail settings, or intelligent microwave ovens that will have your food hot and ready during your arrival, alerted by your mobile device that you have reached your intelligent home. It may also come as the smart pill bottle that alerts the patients or the health centre when one forgets his medication. This will be the era of Smart or Intelligent Packaging which can track, sense and communicate.

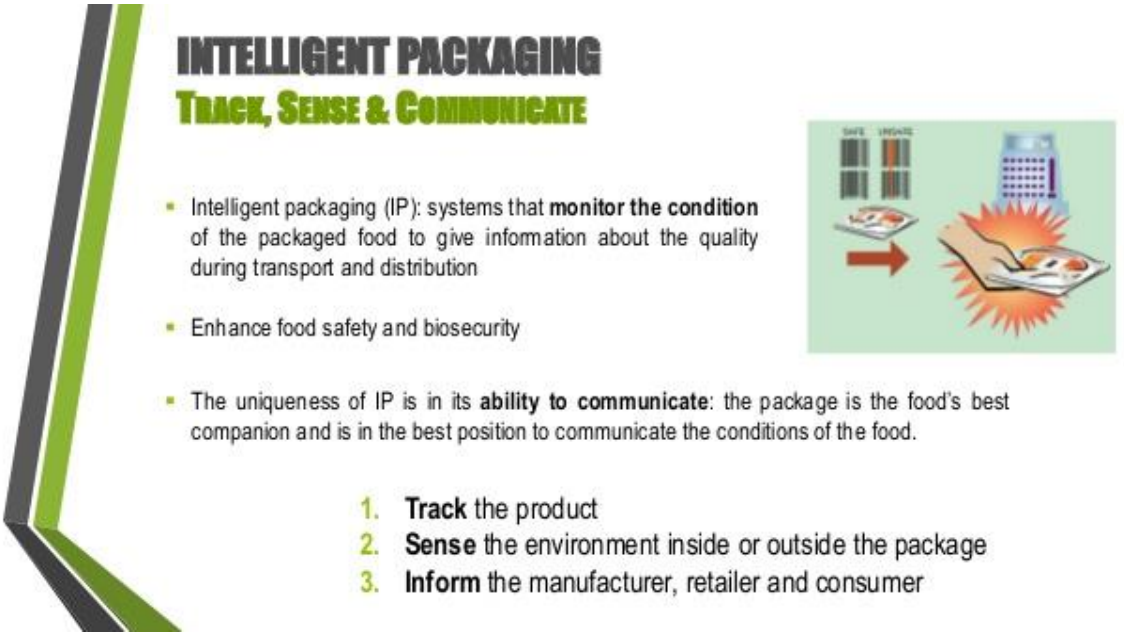

Figure 32: Intelligent Packaging: Track, Sense & Communicate

Smart labels will be used to promote information straight to consumers via ultrathin devices that stream visual and audio presentations, via either touch or motion stimuli or other means of detection. Voice-triggered disposal and safe use instructions on pharmaceuticals and household items can be employed to advise consumers on the correct way of discarding consumed items. Futuristic intelligent packages can also involve waste management and litter checks, recording information for use by regulatory agencies to apprehend litterers and assist recycling firms in sorting packaging materials. Thermo-chromic ink dots may be used to alert when hot food is ready at proper serving temperatures, subsequent to or microwaving or refrigeration (P. Butler 2001)

4.6.5 Innovative Society Scenario

Artificial intelligences such as IBM's Watson system may eventually provide rapid legal counsel with superior 90% accuracy, in comparison to the 70% accuracy rate of human legal experts. Intelligence-based practices may establish cloud-based services capable of answering complex legal questions for counsel and concerned parties. The natural-language capability of the Watson cognitive computing system can be developed to predictively assess court case precedents and verdict outcomes, providing confidence ratings as well as recommend readings for better human preparation in legal casework.

There are anticipated to be significantly fewer attorneys in futuristic settings, with mainly specialist experts remaining in the practice, which seriously concerns the legal fraternities. Once expert systems enhanced with artificial intelligences are deployed, the requirement for human counsel may diminish apart from specialised experts working at big litigation-focused firms.

Watson reportedly assists nursing staff in performing diagnostics of potential cancers, and with much greater precision as well. Facebook has developed pattern-recognition functions that are more capable at identifying faces than most people. By 2030, computing platforms are anticipated to evolve more efficient intelligent functions than those of humans (Paul & Katz 2014).

In futuristic and innovative societies, solar power generation will likely become very efficient in electrical generation at much lower costs. Unit generation costs are expected to drop to the point of forcing many coal firms out of the energy market in the following decades. With electricity comes too cheap, abundant clean and potable water may be processed readily and made available to the entire community through the sea water desalination process.

4.6.6 Military of the future scenario

One may expect, in 2050, fighter jets may be a thing of the past. Drones instead will be everywhere. With the advent of smart and cheap flying machines comes the increasingly endless array of ways in which they might be put to work. Whether blasting objects on the ground may be the current core mission of drones, in future it is expected whatever can be achieved by prohibitively expensive advance jet fighters, can be done by high speed sophisticated drones.

We will have the scenario of fighter drones engaged in deadly dogfights not unlike the video games played by avid gamers currently. The main materials for construction will be advanced plastics and composites since strong, light weight construction materials will be a critical components in these fighter drones design. The main advantages of the drones will be affordable cost of acquiring and maintenance, minimize collateral damage and will not put troops at risk. Of course the current role in search and rescue missions and getting into difficult-to-reach places and cover a lot of ground will be substantially enhanced making them to be indispensable weapons of the future.

Figure 33: Military drones can come in many sizes and shapes

While drones do their work from high above, military robots will be extensively operating on the ground in battlefields worldwide. There will be heavy dependent on bomb-squad robots to inspect and defuse possible explosive devices, all while human operators stayed a safe distance away. In future, the possibility of robots taking over the role of infantry; shooting at each other, securing grounds, are not too far fetch.

On the high seas, future warships would utilize ultra-strong plastics and composites and graphene, armed with weapons that fire near the speed of light and operated by crews a fraction of the size needed by current vessels.

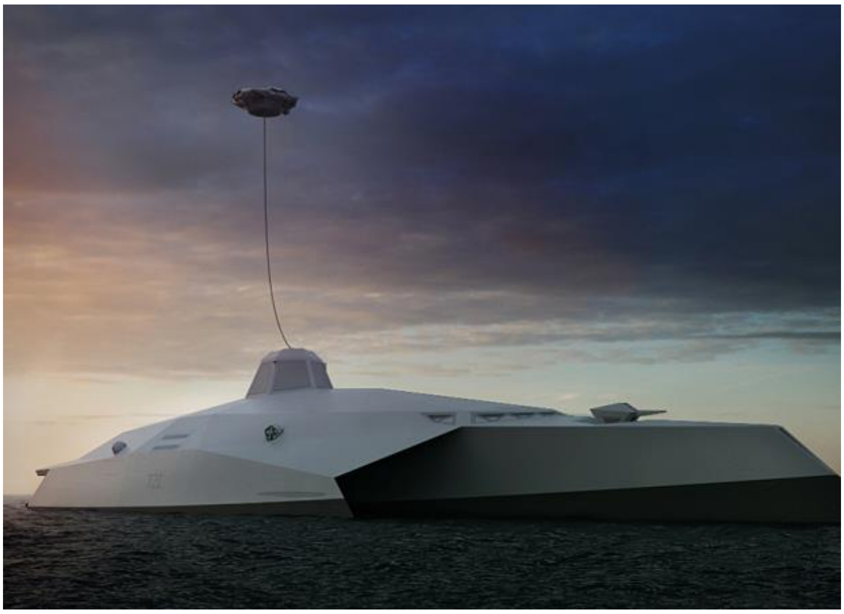

Figure 34 :How warships of the future could look (Mcgarry 2016)

One may expect future battle ships will look very different to what's currently in the fleet. Future vessels will be built out of acrylic ultra-tough composites which are not only lighter than metal, but could be switched between being opaque to transparent by running an electric current through them. This would allow the crew to see through the hull, improving control of close-in battles and improved vision when maneuvering. Wonder material graphene could be used to increase the strength of ships, as well coating hulls to reduce drag, meaning they could sail faster and use less fuel.

Ballast tanks that could be filled with water will be employed so the ships sat much lower in the water, making them stealthy and smaller targets, when they were not being driven at high speeds by waterjets powered by fusion reactors.

Conventional masts could be abandoned for a drone carrying sensors such as radar. This would be connected to the ship by a tether made from cryogenically-cooled carbon nanotubes which would transmit power to aircraft's motors and also energy weapons such as lasers, which could knock enemy missiles out of the sky.

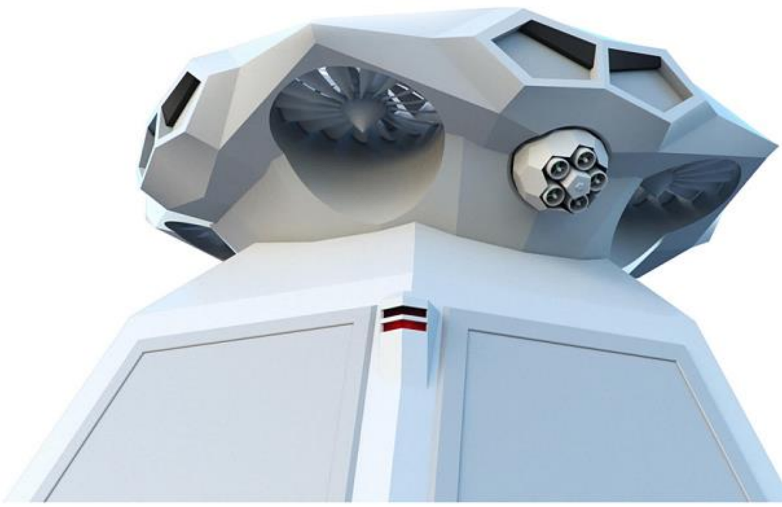

Figure 35: Masts could be replaced by drones which are tethered to the ship (Mcgarry 2016)

Inside the ships, the operations room and the nerve centre of warships and from which its weapons and sensors are controlled and coordinated, a holographic command centre would dominate this space, and commanders would be able to zoom in on areas and change the point, meaning they could focus on land, sea or air. The operations room would have superfast data connections to the rest of the fleet and aircraft, along with headquarters, meaning operations could be commanded from thousands of miles away. Using such advanced technology is expected to cut the number of crew by 80%. By 2050, one may expect, no more helicopters in sight being totally replaced by unmanned military drones that can be utilised at all weathers condition with minimal risks.

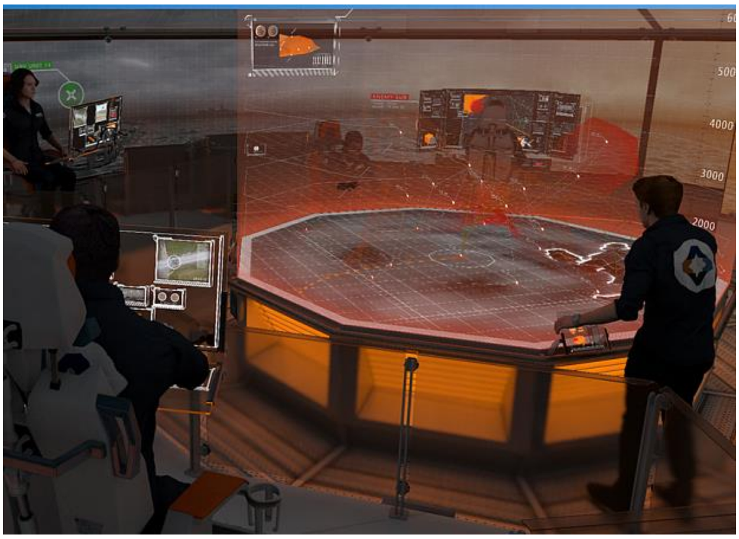

Figure 36: The operations room could be dominated by a holographic command table (Mcgarry 2016)

4.6.7 Smart Electronics & Electricals (E&E) Scenario

Plastic and composite materials have been increasingly integrated into consumer electronic products such as internal parts, enclosures, etc. over the past five decades, as a result of numerous advantages such as lightweight and cost-effective features. The future in E&E is moving to more plastics usage mainly in laminar or flat products and silicon-free organic electronics. Their low cost will lead to widespread use across many applications and industries to make them “Smart” and more affordable. Soon (first generation products are already in the market) rolls of plastics films such as OLED will be commercially manufactured on a larger scale and easily available (See Figure 37).

Figure 37: Organic LED (OLED) rollable TV, display & screen

The Arkema group is jointly conducting research & development with CEA on organic or plastics-based microelectronics (French Alternative Energies and Atomic Energy Commission). Consequently, the on-going miniaturisation of silicon microelectronic devices, based on optical lithographic techniques for microprocessor circuitry engraving, is confronting the physical constraints of silicon-based materials. To overcome these limits that are inherent in extremely small entities, the effort is focused on the development of self-assembling lithographic techniques for polymerised nanostructures. This very encouraging option entails a lower cost of manufacturing and is readily combined with current microprocessor production processes. The group produces a broad variety of specialised polymer compounds of thermoplastic, nanostructured, fluorinated, and piezoelectric types. It invests sizeable research resources into large-area printed microelectronics, such as flexible displays, intelligent packages and textiles, and surface photovoltaics. Their objective is to lengthen systems lifecycles, optimise manufacturing costs, and integrate multifunctional capabilities with similar support levels (Arkema.com).

Usage of organic-based in place of silicon-based compounds made it feasible to innovate a novel range of flexibly transparent and printable parts. Wholly innovative markets have emerged for electronic products, where engineered plastic and composite materials including polyamide compounds feature raised performance levels that can favourably substitute for metals. As well, full ranges of adhesive products are also required, such as multirole acid resin products utilised for metals or plastic composite adhesions in higher performance microelectronic applications.

5.0 GOVERNANCE (ANALYSIS OF CURRENT AND FUTURE NEEDS)

Globalised governances normally comprise a variety of players such as states (USA, Japan, China), regional groups (EU, APEC), multinational organisations (UN, ISO), and worldwide corporations (World Health Organization 2015). Compliance may also be required by the European Food Safety Authority (EFSA) or Codex, a subsidiary of the Food and Agriculture Organisation (FAO) of the U.N. World Health Organisation (WHO). The *Codex Alimentarius* (Latinised "Book of Food") is a group of internationally-recognised conventions, practices, rules, and other recommendations associated with food production, consumption, and safe use (FAO/WHO 1997).

One of the more significant EU regulations is the (EC) No 1907/2006 that involves the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), and Regulation EU 10/2011 that pertains to plastic and composite materials and items that are designed for contact with food. There is no all-embracing federal legislation that regulates the plastics packaging industry, although the Federal government has declared its authority in food, drug, and cosmetic packaging regulation so as to maintain consumer confidence and safety and via regulatory rules such as:

i. U.S. Food Packaging Regulations
ii. Environmental Influence of Materials Utilised in Food Preparation and Packaging
iii. Use of Recycled Content
iv. Prescription Drug Packaging

The percentage of plastics consumed for the electrical and electronics (E&E) sector is about 10% -15% globally. The EU Restriction of Hazardous Substances Directive 2002/95/EC, (RoHS) is a global convention and standard that regulates materials usage, including that for plastic and composite materials for the E&E sector in the EU. This works closely with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC, which fixes targets for recycling, collections, and recoveries of electrical products. This forms part of a legislative solution to the problem of large quantities of toxic e-waste (ECHA 2011).

Plastic and composite materials conventions are devised to specify, test, and evaluate the physical, material, and chemical properties of a broad range of products, as well as the materials with which they are produced. These enable end-users and manufacturers to establish and build a consensus on their products and materials from the standpoint of quality, performance, and safety. Conventions on plastic and composite materials were evolved by the American Society for Testing and Materials (ASTM) and the International Organisation for Standardisation (ISO), which are both broadly received and followed worldwide.

In the area of sustainability (i.e. the 3P's of Planet, People, and Prosperity) for plastics, countries like Japan & global corporations such as Sony are setting the benchmark. The Sony Group reportedly utilises over 13,000 tons annually of recyclable plastic and composite materials (2013) in different products, such as digital cameras, televisions, and audio products, and recording media. Some 40% of the entire volume utilised recycled plastic and composite materials originating from scrap material formed of the by-products of manufacturing processes, at various sites within and contracted by the Sony Group. Nearly 60% is derived from post-consumer recyclable plastic and composite materials, or those produced with used recyclable product/packaging output (Sony Corporation 2010)..

5.1 Current Malaysian governance mechanisms

Current acts implemented for management of the plastics and composite industry as well as regulations and policies are as follows:

i. International Trade and Industry (MITI)
   - Promotion of Investments Act 1986
   - Strategic Trade Act 2010 (STA)
   - Third Industrial Master Plan (IMP3)
   - The National Automotive Policy 2014

ii. Malaysia Industrial Development Authority (MIDA)
   - Malaysia Industrial Development Authority (Incorporation) Act (Act 19)
   - Industrial Relations Act 1967

iii. Malaysian Productivity Corporation (MPC)
   - National Productivity Centre (Incorporation) Act (Amended) A801 (1991)

iv. Malaysian External Trade Development Corporation
   - Malaysian External Trade Development Corporation Act 1992

v. National Solid Waste Management Department (JPSPN)

- Solid Wastes and Public Cleansing Management Act 2007
- National Solid Waste Management Policy

vi. Solid Wastes Management and Public Cleansing Corporation (SW Corp.)

- Solid Wastes and Public Cleansing Management Act 2007 (Act 672)

vii. Food industry – packaging :

- Ministry of Health Food Act 1983

In 2050 it is expected more self-regulations, cross borders protocols and global regulatory frameworks. Governance should have strong input from Technocrats both national and international levels.

6.0 CROSS-REFERENCING (BETWEEN SECTORS)

6.1 Cross-referencing for Plastics & Composites (P&C) Sector with Other Sectors

Figure 38 shows the relevancy of Plastics and Composites (P& C) Sector in relation to other Sectors that have been identified under Mega Science 1.0, Mega Science 2.0 and Mega Science 3.0. It is obvious that P & C Sector plays a vital role as enabler for all the other specified sectors. This provides a very indication on the current and future relevance of P & C Sector is acting an enabling growth role for various sectors in Malaysia.

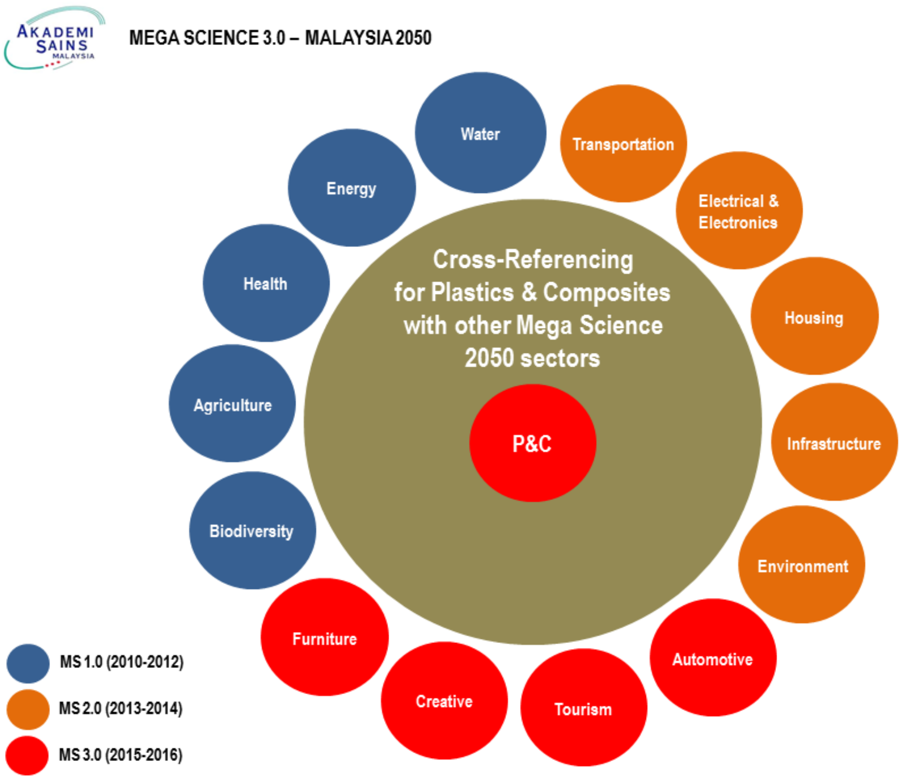

Figure 38: Cross-referencing for Plastics & Composites (P&C) Sector with Other Sectors.

Figures 39 – 41 provide overview of key activities of P & C Sector in various Sectors under Mega Science 1.0, Mega Science 2.0 and Mega Science 3.0. With proper strategies and road maps as given in Sections 7.0 and 8.0, respectively, P & C Sector is set to play its role in generating economic growth both at the local and global scenario.

Figure 39: Cross-referencing for P&C with Mega Science 1.0 (2010-2012) Sectors

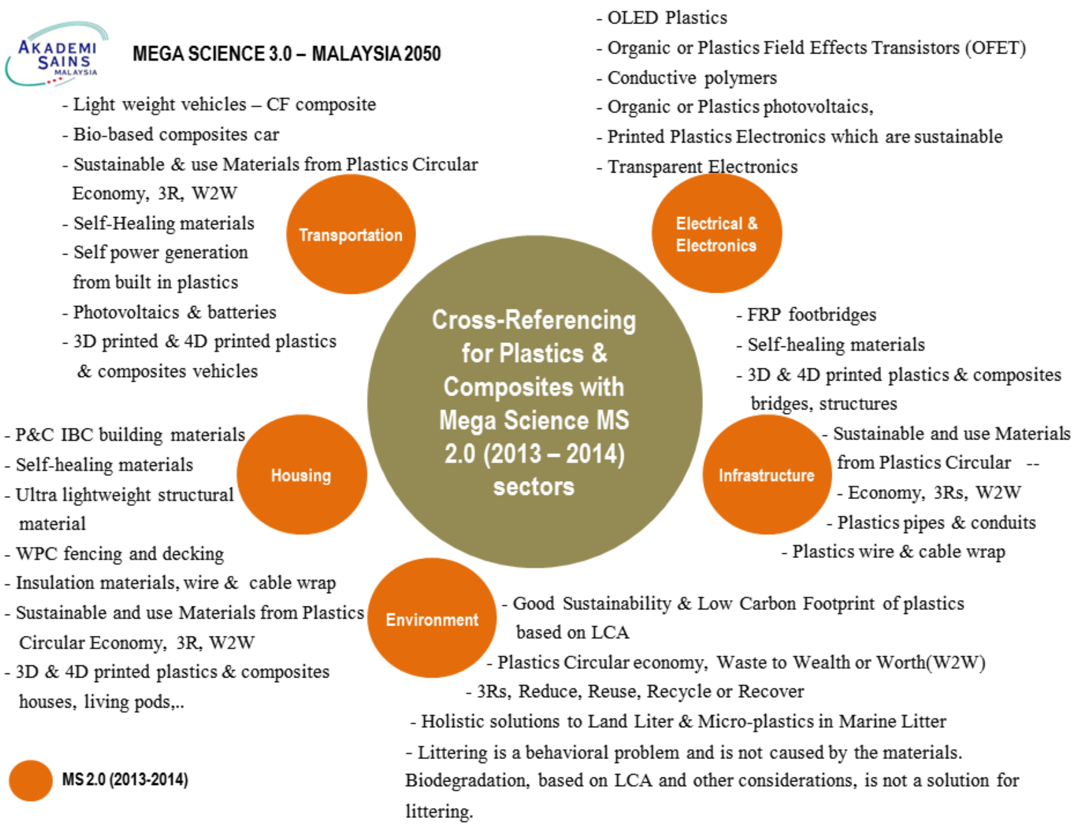

Figure 40: Cross-referencing for P&C with Mega Science 2.0 (2013-2014) Sectors

Figure 41: Cross-referencing for P&C with Mega Science 3.0 (2015-2016) Sectors

Advancement in other related sectors, particularly automotive and aerospace sectors have tremendous impact to developments of plastics and composites materials and technology. The development of modern polymer composite materials and plastics has helped to reduce the weight and enhance the functions, forms, and safe operation of vehicles, while delivering greater value to consumer audiences. To meet the future challenges and opportunities, automakers are resorting to use new advanced plastics and polymer composites while at the same time, increasing the plastics content within the vehicles.

The American Plastics Council issued its Plastics in Automotive Markets - Vision and Technology Roadmap (2001) to cover these initiatives and to advance usage of plastic and polymer composite materials. The roadmap outlined a vision for the application of plastics and polymer composites in automotive and spell out the business and technology strategies needed to provide solutions for the automotive industry. In MPMA Roadmap of 2009, there is also looking into green and sustainable packaging with high recyclable content, emphasis on medical applications of plastics and product miniaturization (lighter, cheaper, down gauging for environment and cost reasons). The plastics manufacturers are expected to be multi discipline to enable them to be the total solution providers.

It envisioned an approach for plastic and polymer composite materials applications in the automotive sector and outlined the commercial and technological approaches required. Producers were encouraged to advance up value chains, from Original Equipment Manufacturer (OEM) to Original Design Manufacturer (ODM), and onto Original Brand Manufacturer (OBM). Convergence of knowledge, discipline and processes will enable product innovations that will spur economic growth.

In 2014, the National Automotive Policy (NAP2014) (MITI 2014) was updated to address the changing industry trends. The plastics and composites industry has continually delivered encouraging performance and play a significant role to affect transformative innovations. Composite materials increasingly provide superior unit energy-absorption capacities, as lightweight yet robust materials for automotive design applications. The NAP2014 goals were to create an additional 70,000 manufacturing jobs by 2020; 80,000 additional aftermarket jobs; RM10 billion in exports of parts and components and RM2 billion in exports of recycled materials and remanufactured components (Mei Mei 2014).

The Malaysian Aerospace Industry has been developing rapidly since the early 1990s. The industry is estimated to record RM9.3 billion turnovers in 2011 whilst creating an employment of more than 15,000 skilled and knowledge workers in various areas. In 2014, Aerospace related industry turnover was RM11.8 billion with 19,400 employments and is to grow to RM55.2 billion in 2030 with 32,000 employments (MiGHT 2015). The Table 2: Aerospace industry growth by 2030, Source: Malaysian Aerospace Industry Blueprint 2030 (MiGHT 2015) excerpted from the Aerospace blueprint illustrating the development of the industry in 2030.

Table 2: Aerospace industry growth by 2030, Source: Malaysian Aerospace Industry Blueprint 2030 (MiGHT 2015)

Growth Levers	Undertakings	Impact
Capture market share	Regional MRO market share	Revenue in 2030 RM55.2 B*
	High value manufacturing market	
	Regional engineering & design market share	
	Local upgrading and integration market	
	Education & training hub	
Stakeholders Facilitation	Apply policies that will impact the future landscape of the industry	Jobs in 2030 32,000*
	Enhance the effectiveness of institutions that have direct influence on the growth of the industry	
	Harmonize civil and military regulations and promote green practices	
	Invest in R&T to develop new capabilities and enhance industry competitiveness	
	Promote aerospace investments through incentives and matching funding	
	Attract and prepare the workforce of tomorrow for Malaysia and the region	
	Capture new market and strengthen local supply chain	

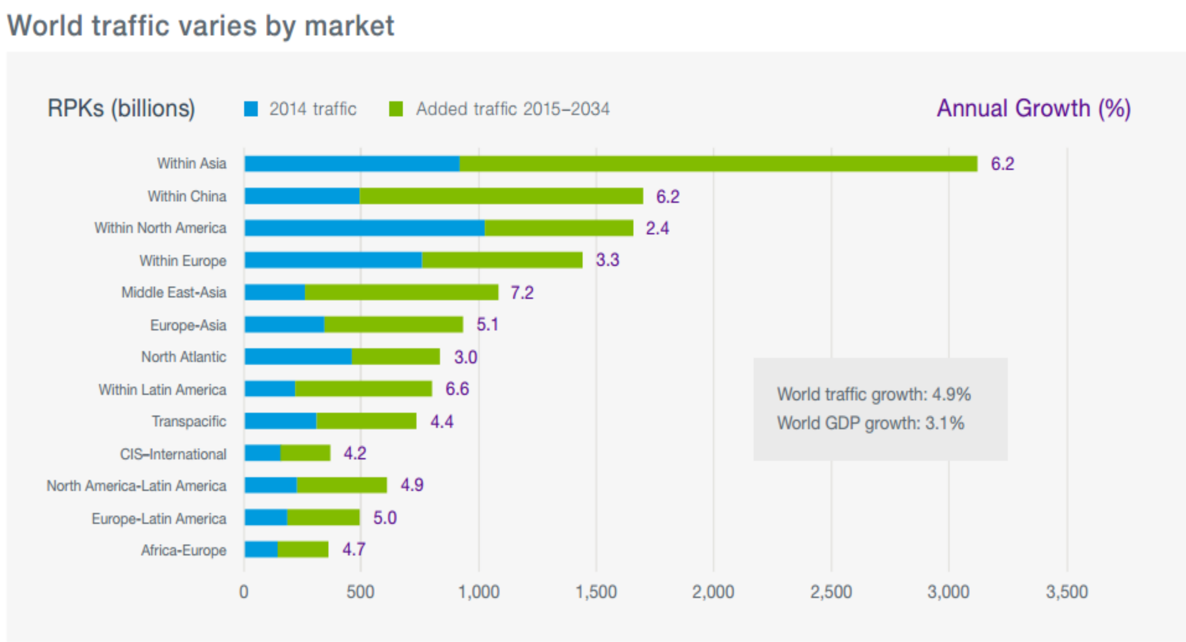

Figure 42: Boeing current market outlook 2015–2034 (RPKs is industry traffic) (Boeing 2015)

The industry is set to grow due to increase of air travel in the world particularly in Asia as depicted by the graph below. Presently, Asian countries comprise the largest global aviation market, representing a billion transits in annual passenger traffic. For the foreseeable future, every year it is projected that about 100 million new passengers are entering the market. Consequently, there is going to be a continual growth of airlines and airports in this region leading to several world's largest airlines and airports. Due to the air travel demand and replacement of aging fleet, the numbers of aircraft required are as illustrated by the Figure 43.

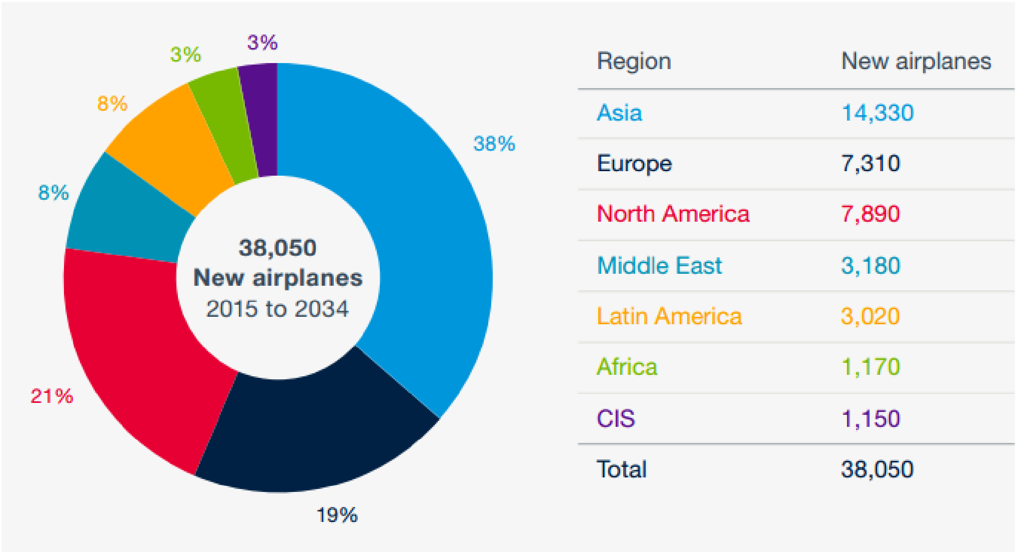

Figure 43: Forecast of world aircraft requirement from 2015 to 2034 by Boeing (Boeing 2015)

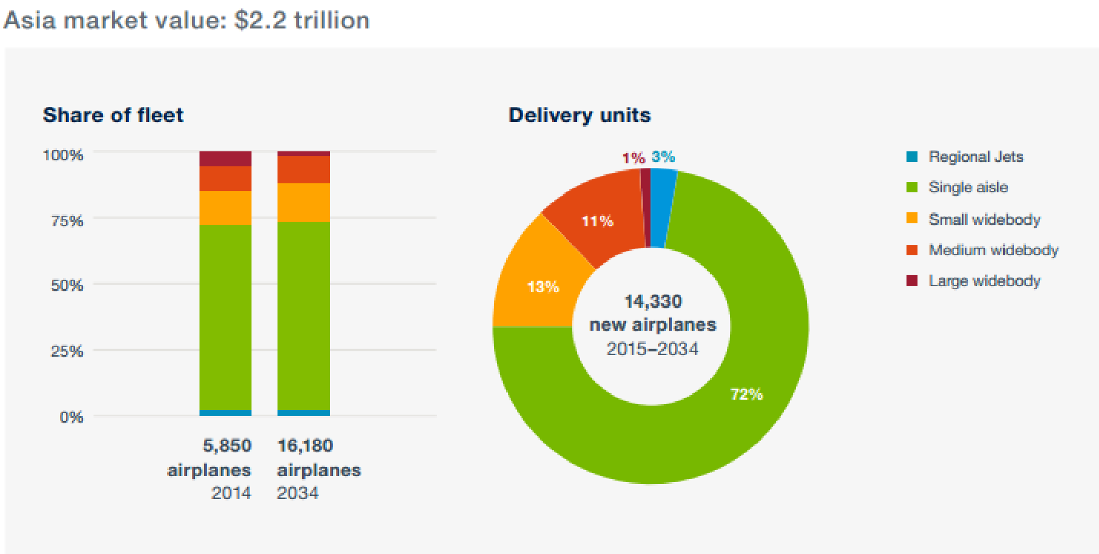

Figure 44: Asia market value forecasted, sources from Boeing (Boeing 2015)

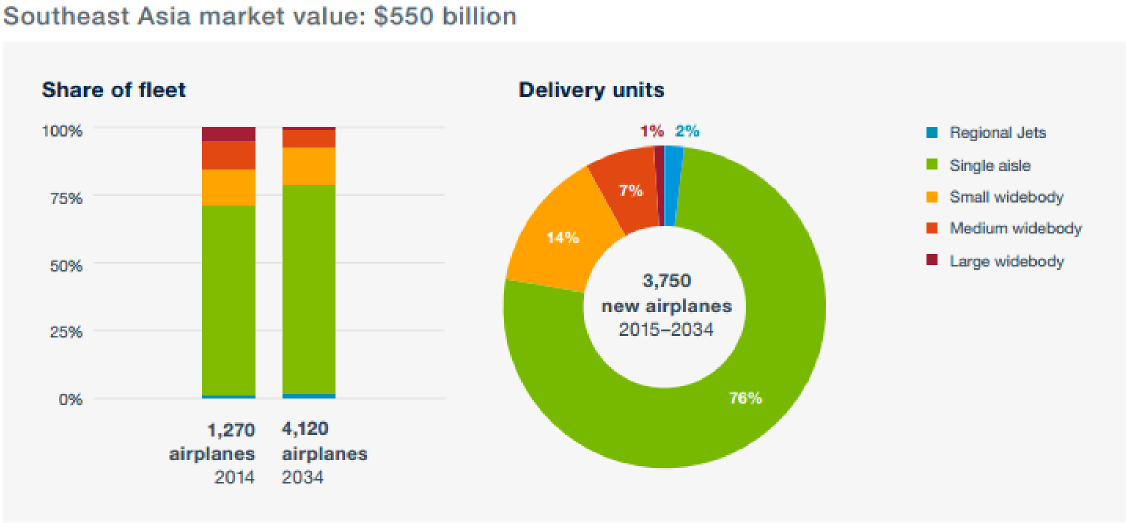

Figure 45: South East Asia market value forecasted by Boeing (Boeing 2015)

Boeing forecasted Asia market value for aircraft delivery is projected to be USD2.2 trillion with 14,330 new airplanes until 2034 and that South East Asia will acquire 3,700 new airplanes, valued at $550 billion. The growth of low-cost carriers (LCC) has been positive and will advance economic growth, leading to the Southeast Asian region becoming the most dynamic worldwide for LCCs. In this respect, the Malaysian government has unveiled the second Malaysia Aerospace Industrial Blueprint 2015 (MiGHT 2015) at Langkawi International Maritime and Aerospace Exhibition (LIMA 2015). These sectors are anticipated to become primary areas of growth in the succeeding 15 years. As referred to Table 3, the Aerospace blueprint addressed Aero-Manufacturing as one of the areas and is represented by these segments; metallic component manufacturing, avionics components manufacturing and composites component manufacturing. Malaysian companies are now recognised as a part of the Global Supply Chain supplying aircraft Composites components to the OEMs such as Airbus and Boeing.

Table 3: Malaysia Aerospace Industry Blueprint 2015-2030 (MiGHT 2015)

7.0 ISSUES OF TALENT DEVELOPMENT/FUNDING

7.1. Issues on Talent Development

The stakeholder engagement through workshops were conducted nationwide in 2015 has gathered that stakeholders in all zones agreed and qualified that human capital development is imperative to the success of the industry. Specific knowledge, skill and attitude (KSA) are required for specific area of specialization within the industry. There are concerns how current system had not resolved to produce graduates to the industry needs. Among the issues are detailed are discussed here:

7.1.1 Labour Market Mismatch

Academies have been producing quantity not matching to industry requirement. At the same time job creation did not grow as much as the graduates produced thus creating labour market mismatch with industry requirement. This is why there are so many graduates in awaiting and job hunting category as depicted in Figure 46.

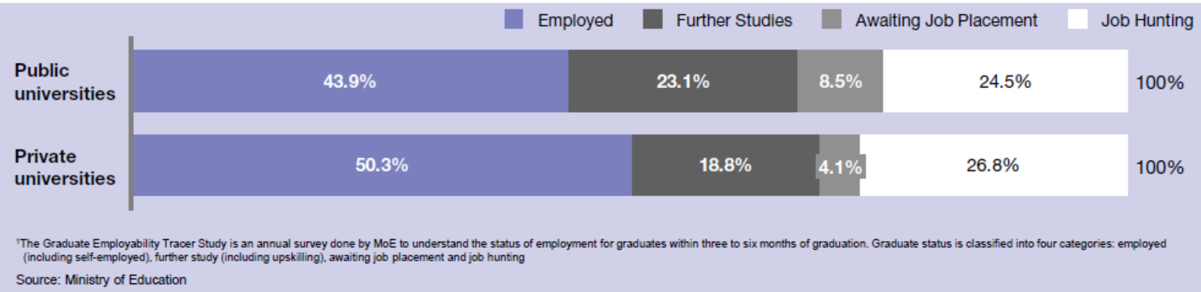

Figure 46: Graduates' employability tracker research outcomes for 2013 (Source: Ministry of Education)

Total students enrollment since 2000 to 2013 are described in Figure 47 below. Evidently the trends of enrollments are upwards thus we can deduce that the number of graduates are also increased, unfortunately the industry job creation did not expand as much.

The excessive reliance by businesses on using unskilled foreign labour has added-up to the problem above. Instead of upgrading local worker to do job better and at high skilled level, many firms are taking short cut by taking low cost foreign worker to increase profit. This in turn impedes productivity growth and undermines the creation of skilled job opportunities. The government should provide incentives for companies to upgrade their workforce.

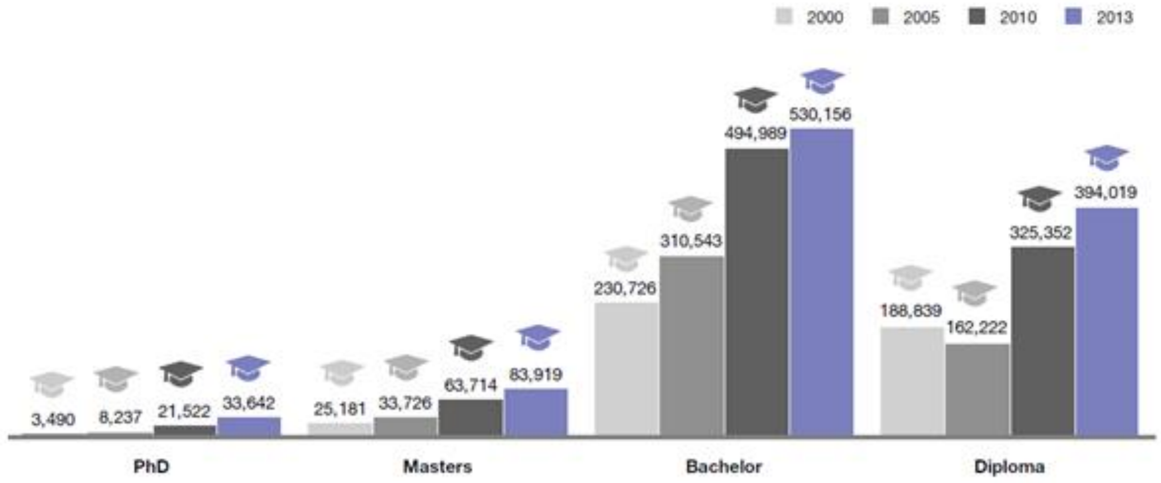

Figure 47: Enrolments in public and private universities, and university colleges, according to study levels (RMK 11) (Economic Planning Unit, Prime Minister's Department 2016)

The industry requires a lot more Diploma and Certificate levels whereas the academies produce so many Bachelor levels which create one of the mismatches. The is clearly shown in Figure 48 where Diploma and Certificate levels are categorised as Semi Skilled manpower and Bachelor is categorised as Skilled manpower as termed by the Economic Planning Unit. It is worth to mention that this is another mismatch where the terminology of semi-skilled and skilled manpower category carries different meaning between industry and agencies.

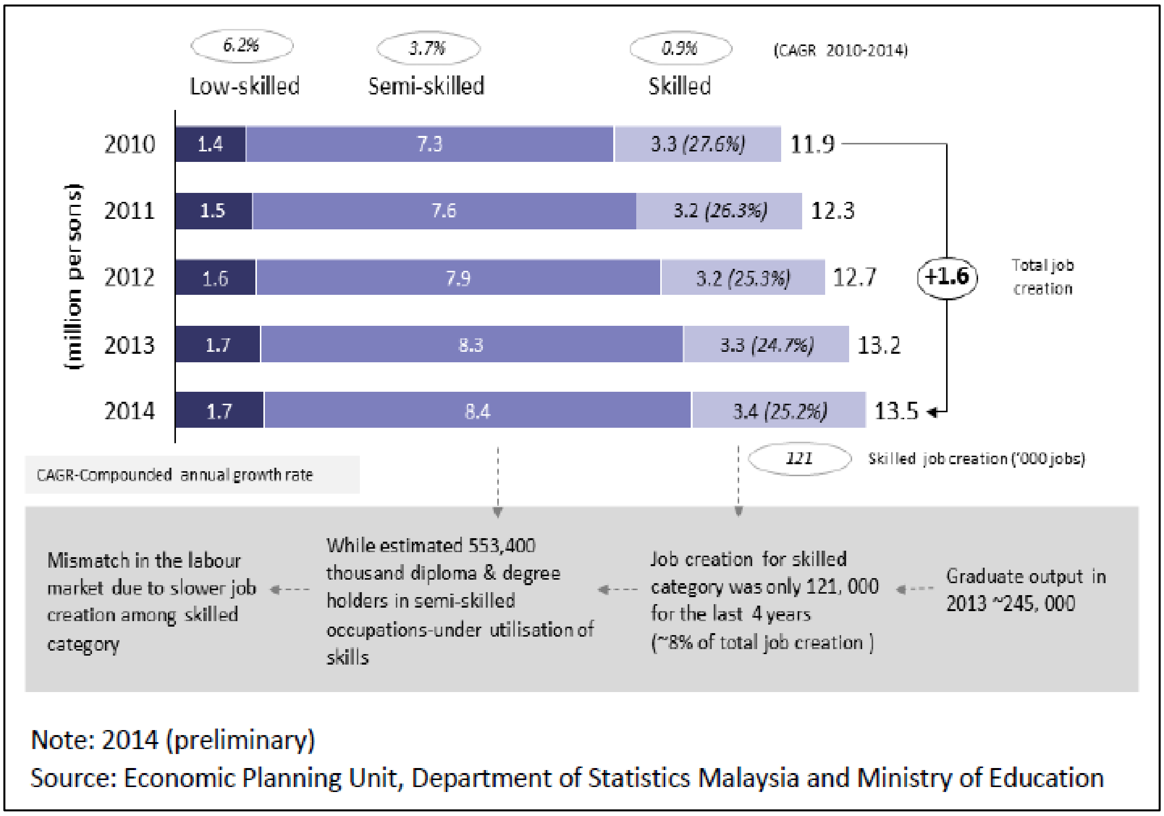

Figure 48: Employment according to skills categories, 2010–2014 (Economic Planning Unit, Prime Minister's Department 2016)

7.1.2 Academia producing quality not matching to industry requirement

Another issue pertinent to the graduates is that they are not ready to work when they graduated from the academies. There is a gap of industrial requirement to what is being produced by the academies. Basically they are not ready to work after completion of studies. Figure 49 is a quote from H.E Dr. Gunter Gruber is the current German Ambassador to Malaysia commented on the quality mismatch within the graduates.

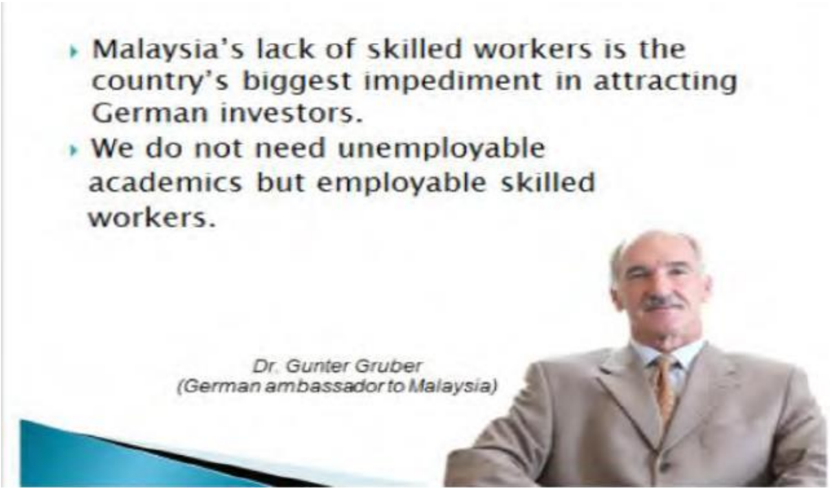

Figure 49: Quotes: Dr. Gunter Gruber, German Ambassador to Malaysia

7.2 TVET and Government strategies

The proficiencies of Malaysian workforces are essential for skilled progress in economics transitions, as well as the realisation of the government's plan to achieve developed-nation status by 2020. Based on Economics Planning Unit (EPU) measures, labour demand, particularly in the Technical Vocational Education and Training (TVET) sector, is anticipated to grow with the establishment of the National Key Economics Area, or NKEA.

By 2020, the NKEA workforce requirement should total 3.3 million, comprising some 1.3 million TVET graduates. If government agencies do not launch initiatives to upgrade workforces, there would emerge a demand shortage of approximately 350,000 workers through 2020. Thus, the requirement for 1.3 million quality-trained TVET workers would not be satisfied in this scenario. Of a current general workforce comprising some 12 million members, only 28% are trained personnel. This currently falls short of the government's 40% minimal target for 2020 (Rasul et al. 2015).

The Plastic and Composites industries are also suffering from unavailability of skilled manpower to support the industry growth. Human Capital is one of the big ticket items we have to look into even though the government had spent countless billion of ringgit channeled through at least seven ministries into preparing students to become semi-skilled, skilled manpower, blue collar and white collar professionals.

The issues and challenges of TVET in Malaysia currently are as illustrated by the fish bone diagram as in Figure 50 where issues and challenges were clustered into four clusters:

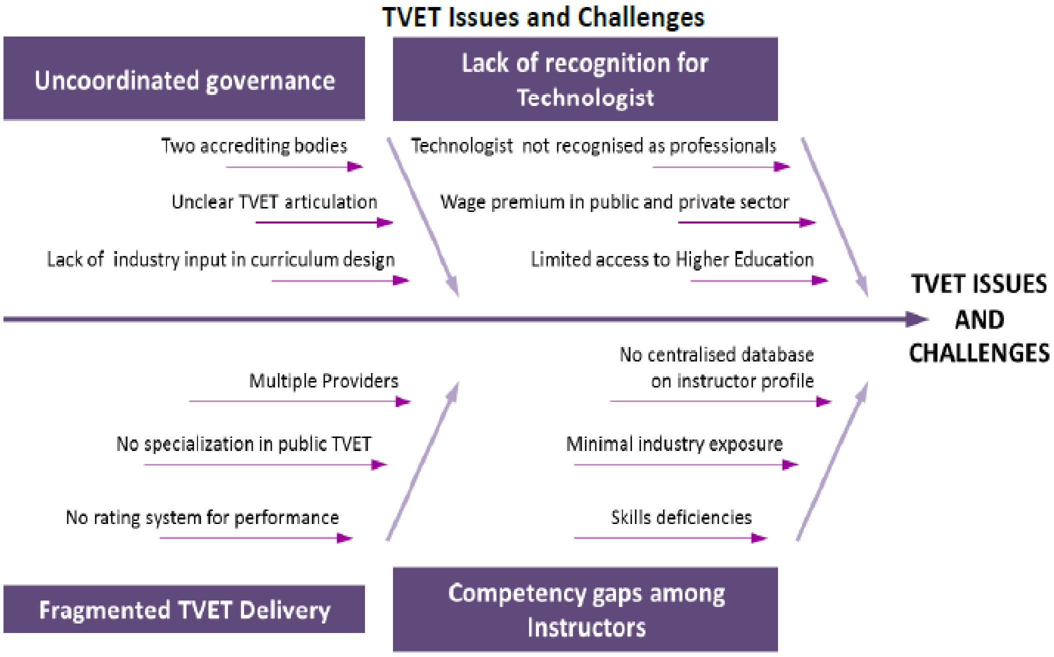

Figure 50: TVET issues and challenges, source: RMK11 (Economic Planning Unit, Department of the Prime Minister, 2016)

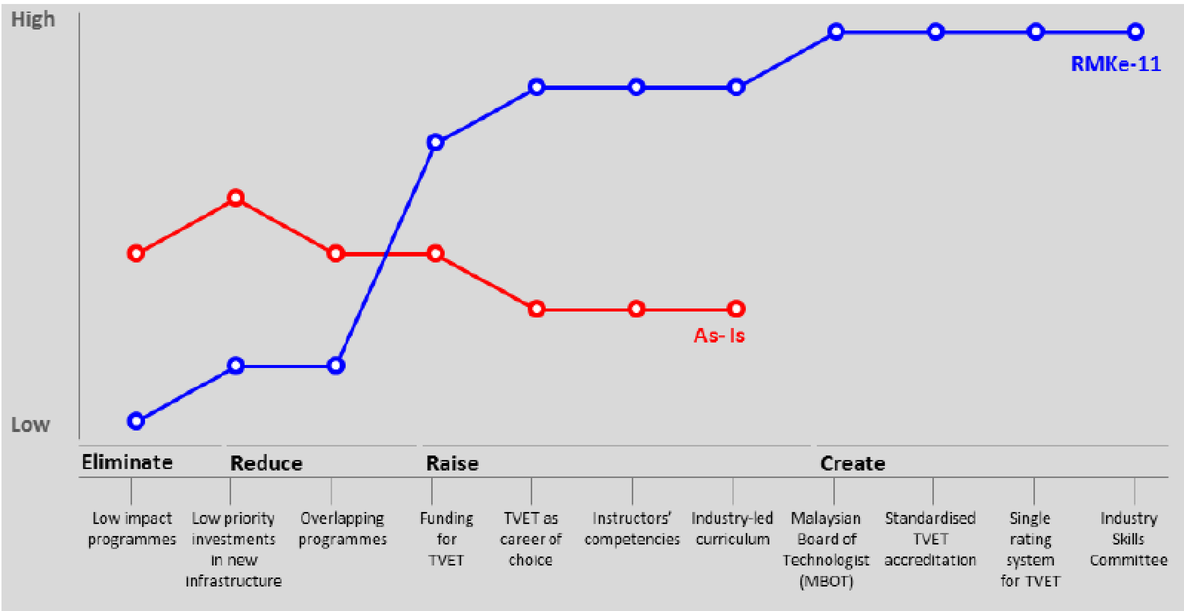

Figure 51: Strategy Canvas for TVET, source: RMK 11 (Economic Planning Unit, Depertment of the Prime Minister, 2016)

In order to resolve the TVET issues and challenges, the government had specified three strategies by focusing on eleven initiatives, as shown in Figure 51. This figure compares the focus given into each issues and challenges between current situations to the planned ones in RMK11. There are 3 issues and challenges needed to be eliminated and reduces while four issues and challenges to be raised or improved and there are four new initiatives to be created. There are three programme approaches for sustaining their systematic implementations, as follows:

i. ***Approach 1*:** Reinforce TVET governance for enhanced management, via the rationalisation of nationalised qualification frameworks and the harmonisation of different rating schemes, through public as well as private TVET organisations, via the:

- *Introduction of a single scheme for accreditations*
- *Coordination of TVET organisational ratings for enhanced comparisons*

ii. ***Approach 2***: Upgrade the qualities and deliverables of TVET courses to enhance the prospects of graduates, by facilitating industrial leadership in curriculum evolution, removing duplications of course and resource items, upgrading cost efficiencies, and increasing TVET budgets to raise enrolments, via the:

- *Facilitation of industrial courses that lessen mismatches in proficiencies*
- *Establishment of National Dual Training Systems (NDTS)*
- *Elimination of low-impact courses and the minimisation of programme overlaps*

iii. ***Approach 3*:** Upgrade TVET brandings to raise awareness. This can be attained via promotions that highlight TVET tracks as appealing professional careers, via the*:*

- *Enhancement of TVET graduates' prospects*
- *Extension of TVET graduates' access to higher educational opportunities*

RMK-11 will emphasise numerous programmes regularising TVET deliverables that are appropriate to dynamic economics as much as demand-driven industrial conditions, thus ensuring the supply of excellently-trained workers. These programmes should offer empowering settings and support schemes to guarantee the success of TVET initiatives. Improved productivities and superior career opportunities in workforces are anticipated to raise the average living standard (Economics Planning Unit (EPU) 2015).

7.3 Workforce skills development and training

7.3.1 Lifelong Learning and National Dual Training Scheme

To respond to increased technology transitions and knowledge intensities in the economic landscape, unceasing effort must be put into evolving knowledge-based cultures in Malaysia. Lifetime learning is essential for progressing such knowledge-intense economies. The Third Outline Perspective Plan (2001-2010) summarised programmes for the promotion of lifetime learning that involve inexpensive and accessible education and training via ICT-related or internet-based courses, thereby incentivising companies to encourage lifetime retraining and education (Pang et al. 2010)

The plastics industry has also acknowledge that “Education and Training” as one of the Technology priorities in MPMA vision of roadmap of the Malaysian Plastics Industry as included in Figure 52 and this shows that the industry also already “buy-in” the lifelong learning concept.

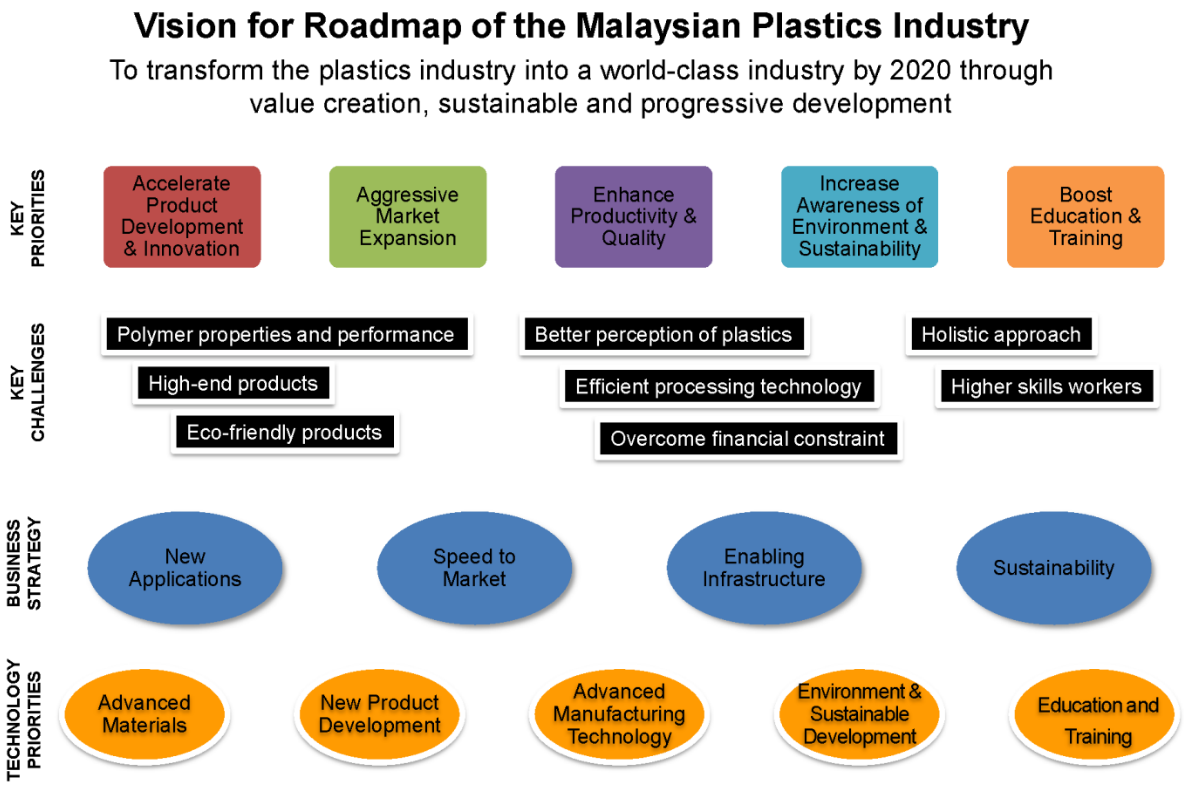

Figure 52: Vision for roadmap of the Malaysian plastics industry (Malaysian Plastic Forum (MPF) 2012)

The plastic and composite materials sector employs some of the best technologies and plant, but much progress in technology acquisition is unfortunately hindered by an expanding human resources gap in the types of industrial skills that drive progress. To meet this proficiencies challenge, the Malaysian Plastics Manufacturer Association (MPMA) introduced in 2012 their Talent Development Programmes in support of the sector's specialised training and technical requirements, in order to meet rising demand as well as sustain future growth.

Moving forward, MPMA is investigating the introduction of online technical training programmes aimed at helping employees build skills on their own and in tandem with existing workforce development programmes. Creating a well-trained workforce can help improve quality, cycle time, communications, reliability and safety, while reducing costs and downtime. MPMA believes that the plastics industry will not realise its full capacity for growth and production unless companies take an active approach to workforce development to push the Plastics Industry into creating higher value added products. This is illustrated in the multiple variables graph shown in Figure 53.

The bottom axis is the scale for skill level from 1 to 10 (this is a qualitative scale used by MPMA). The bell curves at the bottom tier of the figure represent the distribution of the workers with various skill levels. The bell curve (blue line) on the right expresses the distribution of the skill of workers at the present time. Notice the curve is skewed towards the lowers skill with a higher distribution of worker in the lower skills at levels 3 and 4. In the short and medium term, the objective is to shift the blue curve towards the orange curve to the left (upgraded the skills of the workers) and also skew the orange curve on the left with a higher distribution of skill workers in levels 6,7 and 8. In the long term, the objective is to shift the whole orange curve to become the green curve where the median skill level is at level 7 and there will be a much higher proportion of skill workers at levels 8 and 9 (we consider skill levels of 8 & 9 to be world-class). The shift of the workers from the present low skills to very high skills (world-class) can only be achieved by a conscious and focused effort to train the industry workers in higher skills training. The upper tier of Figure 53 shows the relationships of the value add between lower skill and higher skill workers represented by the top blue curve. The illustration shows that the values add of a level 8 worker is twice that of the level 6 worker. Hence in order for us to achieve a high income society within manufacturing, we need higher skills workers of world class skill levels.

From the above, we can see that in order for our industry to move towards higher value added, higher skill training is of utmost importance. A point to add is that many of our local

"Institut Latihan Perindustrian" are covering courses in levels 1,2 and 3 which is inadequate in wanting to move the nation towards a high income society.

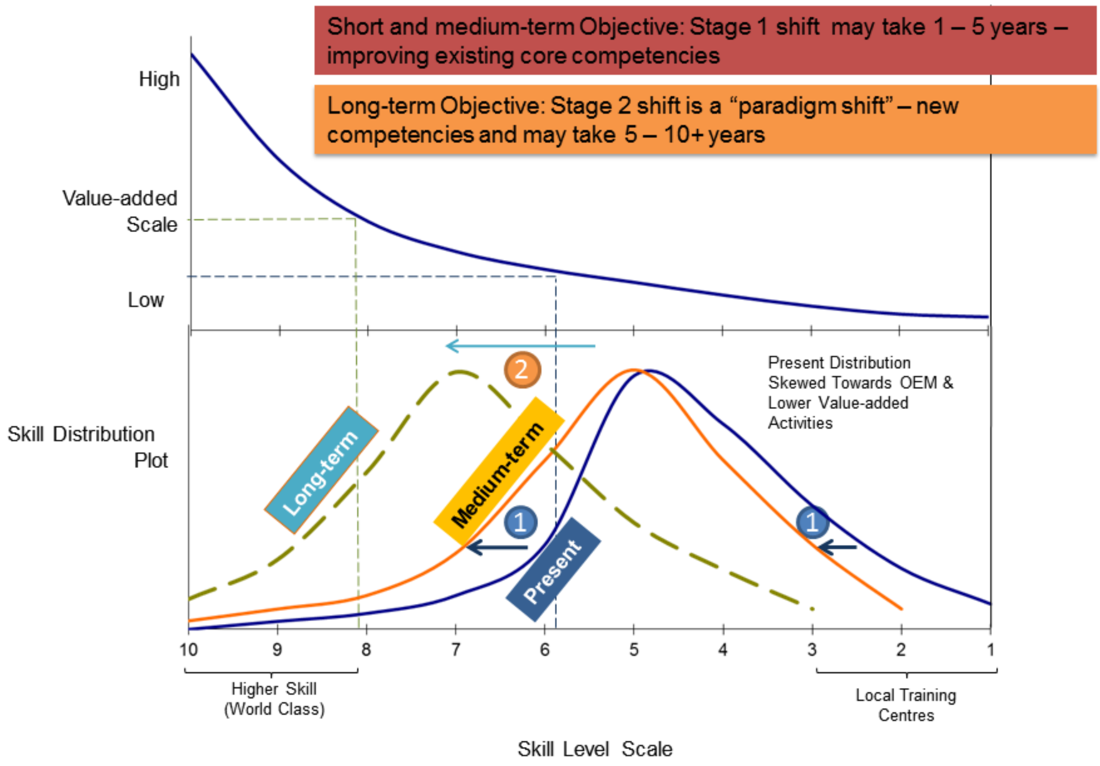

Figure 53: Relationship between Value-added contribution vs. Skill Levels & a depiction of our current skill distribution in the Plastics Industry (Source: MPMA) (MPMA Technology Roadmap 2011)

In 2012 the composites industry has experimented with National Dual Training Scheme (NDTS) with great success and believed the method could enhance the development of the composites industry skilled manpower. The curricula known as National Occupational Skill Standards (NOSS) were jointly developed by Department of Skill developments (DSD) and industry professionals, towards developing workers' skills in ideal alignment with the sector's technical needs.

7.3.2 Lack of local trained personal to go into higher value chain

There should be a holistic and integrated talent management strategy that can effectively deliver the desired objectives where challenges may come in the form of globalisation, multi-generational workforce, and dynamic flow of labour across borders, outsourcing and emerging markets.

Figure 54: Talent management platform on demand infrastructure (Alchemus 2013)

7.3.3 Talent development in the USA

To develop the succeeding generation of plastic materials leadership, the American Plastics Industry Trade Association innovated their Future Leaders in Plastics programme, or FLiP. In this approach, a professional cohort under 40 years of age participated in a programme designed to offer younger plastics-industry professionals opportunities in training and exposure that are needed to progress their careers and the overall sector.

The primary aim is to generate resources, training, and opportunities for the career growth of younger professionals as well as their engagement with SPI leaders. The programme also connects and cultivates new industrial talent, offering the opportunity for these younger staff to network among themselves and with more established professionals in the industry (SPI: The Plastics Industry Trade Association 2015).

7.3.4 Industry job growth continues

As per SPI's President Bill Carteaux, the US plastic and composite materials industry is attaining new global employment, modernisation, and product revenue records (SPI: The Plastics Industry Trade Association 2015). The sector has a workforce of around 1 million, reporting a shipment record of 427 billion dollars. As well, further employment increases were made possible with significant innovations.

Similarly, the Malaysian plastics industry is projected to grow between 6-10% in the next 5 years according to MPMA. As such new jobs will be created that demand higher skills as we continually aspire to move up the value chain. We need to train and prepare skilled workers, technicians, engineers, designers, professionals and etc. to fill these jobs.

7.4 Recommendations for talent development for Plastics and Composites

Academia/TVET, industry and government agency (JPK & MQA) to sit together and forge a national industrial/technical training/education blueprint towards 2050 so that these objectives are achieved:-

i. To avoid duplication of effort
ii. To share facilities and resources
iii. Align and match future talents with :-
    - Academia needs
    - Industry needs
    - Technology advancement needs (product development)
    - Sustainable issues (wealth out of waste, recycle)
    - Globalization issues (e.g. TPPA, FTAs)
iv. To forecast future manpower needs in creating higher value chain
v. Design industry specific courses for plastic and composite
vi. Industry expert and academia and JPK to sit down together to come up with syllabus that meets the industry requirement for current and future. It is recommended that education and training have 2 tracks. The academia will run the courses with more academic contents while the Industry will establish syllabi for technical training at multiple skill levels that are very specific to the industry needs. However as

mentioned earlier, there will be the need to cross reference between the academia and the industry to ensure there is relevance and synergy of both tracks.

vii. Create an entity named Industrial Steering Task Force (ISTF) comprising of creditable trade associations such as MPMA to oversee and monitor the forging of a national industrial/technical training/education blueprint for Plastic & Composites.

viii. Malaysian Plastic Institute is to be set up and coordinated by MPMA as it is a sub set of the ISTF.

ix. Empower the ISTFs by appropriate funding

x. Extend reporting on the Human Resource Development Fund, essentially expanding the facility to other economic sectors, as skill evolution is critical to workforce and employer advancement and government regulation.

xi. Distribute funding for skill training suppliers only after analyses have been conducted on the industry's actual training requirements, so as to lessen discrepancies in skill matching.

xii. Acknowledge that various kinds of proficiency training are needed by various industries and workforces, avoiding the concept of monolithic programmes.

xiii. Stipulate an educational and living allowance for every worker who has been dismissed or laid off.

xiv. Offer vocational training for dropout students, perhaps under the Department of Skills Development, so that they may be armed with the required proficiencies and certified appropriately with degrees or diplomas.

These initiatives offer opportunities to nurture bigger pools of home-grown talent, by upgrading technical skills in manufacturing Research & Development, through technological transfers and education (MIDA 2014). Industrial modernisation will continue accelerating as newer market players and innovative products transform product R&D, manufacturing, and commercial models. Product categories with innovations involve mixes of product classes and converging technologies in areas such as microelectronics, ICT and IoT developments, and additive manufacture (3D printing), which are frequently combined in medical products (MIDA 2014). Established regulations that support entrenched industrial concerns along with government programmes and incentives will enable the Malaysian industry to achieve robust growth and enter into foreign markets

8.0 PROPOSED STRATEGIES

Overall, our view of a good strategy for the future should have the following key elements which embraces Sustainable Development i.e. Environment, Social, Economic factors or 3Ps (Planet, People, Profit). Also known as *Triple bottom line,* it aims to measure the 3 most important indicators viz. environmental, social and financial performance of the nation over a period of time. Only when nations measure their social and environmental impact will we have socially and environmentally responsible nations.

With the Objective to ensure sustainability of plastics and composites industry as Key earner to the nation and the aspiration to move the plastics and composites industry from top 20 in Asia to top 10 by 2050, the following Strategies are proposed.

i. Enhance innovation culture within the plastics and composites industry and business driven R&D by creating a conducive environment to build, nurture and retain the much needed brainpower to open up new frontier in research excellence. The fields of interest to focus on will include:

   - Microelectronics (OLED, photovoltaic, transparent electronics/transistors)
   - Additive manufacturing (3D printing)
   - Advanced materials (Self-healing, lightweight materials, smart packaging, bio-based materials)
   - Environment and sustainability (Waste to Energy, micro irrigation, wastewater membrane filtration, off-grid desalination).

ii. Generous government funding and incentives to research, development and commercialisation (R, D&C), at par with developed nations, i.e. 2% of GDP. In 2012, Malaysia invested 1.1% GDP while Korea spent 4.4% GDP. Approval of R, D&C should be done objectively by impartial distinguished experts in the relevant fields. Nevertheless, readily accessible funds alone are not enough, if the ensuing projects are not subjected to effective Monitoring & Evaluation (M&E) process. Monitoring refers to the internal collection and analysis of information about a project or programme while Evaluation means there should be a periodic retrospective assessment of a completed project or programme. The R, D&C evaluation process should be conducted by competent external independent evaluators.

iii. The ILB must be enabled as the exclusive monitoring and coordinating institution that can rise above academic and research organisations with regards to plastic and composite materials R&D and usage.

iv. Systematic and integrated strategies are required to supervise national resources via non-harmful ways and means, which successive generations can benefit from. Governmental and industrial recognition of the necessity for rethinking the handling and removal of plastic materials is critical to the establishment of newer recycling schemes for the promotion of efficiencies as well as the conservation of resources and the reduction of polluting wastes.

v. Facilitate industrial initiatives for advancing firms up value chains and for differentiating them from their worldwide rivals.

vi. Envision smart communities that put members' well-being ahead in futuristic settings, where all can pursue prosperous and vital lives. This concept involves the ability to fuse into a single harmonious whole a trio of differing views, i.e. Social, Digital, and Green worlds. Such a community is a self-sustaining social identity that is digitally intelligent, socially successful, and environmentally maintainable. A Smart Community empowers its members to sustain their personal and communal well-being. Approaches to evolving the essential scheme of smart community types among others comprise developments in:

- Resource considerations – computing assistance for decentralised governmental structures that encourage responsiveness to localised needs and settings, to include formal processes that encourage citizens' involvement in low-level decision-making that concerns the distribution and prioritisation of localised resources.
- Healthcare – sustaining decentralised healthcare workforce and facility resources, to include public health services for lower-income communities. These would comprise informational and educational initiatives that involve tiered diagnostic

schemes that guarantee the effective utilisation of limited common health resources

- Dwelling mapping – computerisation of common land usage and dwelling registries to make available more useful information on rents, rental grievances, job orders, etc. in every local community. These would include educational and support provisions for furthering employment that sustains personal and community land rights and utilises the collected knowledge, to uphold the rights of those renting or living in unofficial dwellings.
- Infrastructural enhancements – improve incident-reporting processes such that citizens can readily report common infrastructural problems in a combined manner, according to location. Such computing support should be transparent to users, enabling interpersonal and communal cooperation as needed in order to elicit vigorous responses.
- Local Governmental enhancements - provide for public examination of municipal budget reporting, to include funds for educating and assisting members with inadequate training, and to conduct budgetary reviews to ensure that funds are properly expended and equitably distributed among members to ensure proper plastics and composites wastes management

9.0 ROAD MAPS

The Plastics & Composites (P&C) Industry 2050 Roadmap were developed which included inputs from the six stakeholders' engagement workshops held across Malaysia from June 2015 to March 2016. This is to obtain a wide range of opinions and views in addressing the issues being discussed, with the ultimate aim of giving the stakeholders a sense of ownership of the outcome of the consultation and eventually a stake in the planning and design of the future of Malaysia.

The objectives of the above roadmap are as follows:

i. It provides relevant insight and guidance for the Government of Malaysia in relation to the Plastics & Composites Industry Sector
ii. Ecosystem to sustain Smart Communities via Wealth creation- Industries/sectors with potential to create wealth and as well as fuel/catalyst economic growth. Also, being an Enabler for good and strong governance.
iii. Foresighting for the next 35 years (i.e. from 2015-2050) from local, regional and global perspectives. The global views include technology, business, governance, and sustainability
iv. Present issues, challenges and opportunities

The plastic and composite materials industrial team has evolved a roadmap designed to transition Malaysia's plastic and composite materials sector to world-class standards. It will contribute significantly towards wealth creation and economic growth in establishing smart communities in Malaysia by 2050.

Towards attaining the 2050 goal of "Smart Materials through Smart Technologies targeting Smart Applications for Smart Communities", the approach has been assigned to the plastic and composite materials sector, described by four core fundamentals. These are the New Application, Speed to Market, Enabled Infrastructural, and Sustainable Elements.

The scheme therefore emphasises four primary areas of developmental focus, comprising New Products, Advanced Materials, Advanced Manufacture, and Sustainability. Tables 4-7 provide more information.

Table 4: Roadmap of the Plastic and Composites towards 2050 – Advanced Materials

Focus Area	Short Term(2015-2020)	Medium Term(2021-2035)	Long Term(2036-2050)
Advanced Materials	1. Readily available & Cost effectiveness (better properties to less material consumption with high output) 2. Improved performance 3. New building materials from industrial wastes 4. Jump Start R&D in Conductive polymers, Organic photovoltaics, Organic LED (OLED), Organic Field Effects Transistors (OFET) 5. Strengthen & grow position in key resins & substrates such PE, PP, PET, PC, PA & Epoxy. 6. Special nano composites (carbon nanotubes, polymer metal fibre, nanofibers, graphene, nano platelets) 7. Low-cost precursors: PAN textile, lignin and polyolefins 8. Shorter cure time matrix resin	1.Plastics from renewable/biobased feedstock –from 3Rs, W2W & New Plastics Economy 2. Self-healing materials 3. Smart multi-functional material or materials 4. Malaysia Asia Pacific key player in Conductive polymers, Organic photovoltaics, OLED & OFET. 5. Malaysia to be a key regional player in key resins & substrates.	1. Self-healing technologies established (esp for Smart Packaging, Clothing, EE, Transport, Homes 2. Self-energy generation/regeneration materials (esp for Smart Packaging, Clothing, Electrical & Electronic , EE, Transport, Homes) 3. Super Plastics or Polymer i.e. >5 properties in 1) 4. Malaysia Asia Global key player in Conductive polymers, Organic photovoltaics, OLED & OFET. 5. Malaysia to be a key global player in key resins & substrates.

Table 5: Roadmap of the Plastic and Composites towards 2050 – Advanced Manufacturing Technology

Focus Area	Short Term(2015-2020)	Medium Term(2021-2035)	Long Term(2036-2050)
Advanced Manufacturing Technology	1. Cost Effective & Energy efficient manufacturing processes 2. Rapid manufacturing technology 3. Overcoming processing limitations of materials 4. Precision controls on processing machinery 5. Multi-skill, multi-discipline personnel 6. Initiation of Industry 4.0 (which includes robotics via Cyber-Physical Systems, Internet of Things and Internet of Services). 7. Out-of-autoclave composite processing 8. Fibre placement technology 9. Long Fibre Thermoplastics (LFT) technology	1. Additive Manufacturing or 3D printing is key and widely used 2. Complex Multilayer (including micro, nano scale) & multi-materials extrusion, moulding & processing 3. Artificial Intelligence (AI) control systems 4. Industry 4.0 widely practised 5 .Readily available Smart materials for smart applications such as smart packaging, transport, EE, clothing & housing. 6. Integrated Bldg System(IBS) Casting Plant for smart homes 7. Malaysia a major Asia-Pacific player in plastics & composite based smart materials, photovoltaics, printed electronics, body thermal batteries	1. Industry 4.0 (5.0?) a ”culture” 2. 3D printing a key tool in “Innovation for All” culture 3. Lego/modular concept of house/Integrated Bldg System-IBS house widely practised 4. Malaysia a major Global player in plastics & composite based smart materials.

Table 6: Roadmap of the Plastic and Composites towards 2050 – Product Development

Focus Area	Short Term(2015-2020)	Medium Term(2021-2035)	Long Term(2036-2050)
Product Development	1. Products with sustainability elements/eco-friendly: Light weight structures/EEV, Biomass medical devices 2. Organic (mainly plastics based) OLED, printed Electronics, photovoltaics, body thermal batteries, RFID..etc 3. High-end & High Touch smart products eg -- Bio-mimetic and Hydrogel fabric for Smart Clothing: Food Packaging for longer freshness & shelf life (Active, Breathability) 4. Jump Start key Smart Applications i.e. Packaging, EE (Electrical & Electronic), Transport, Housing.	1. Low cost and efficient Organic based (mainly plastics) electronics, photovoltaics, chips & transistors vs Inorganic (Silica based) ones. 2. Organic (Plastics based) printed electronics, RFID etc on packaging materials 3. Malaysian standards established for Smart Applications. 4. Commercialization of Smart Packaging, E&E, Clothing etc. Certification of these products 5. Commercialization of drug delivery system, Micro/Nano packaging, Medical Devices (Bio-based) and Smart House, Transport (including Flying Car). 6. Regulations and rules for safe, efficient Smart Transport esp flying cars in place 7. Convergence of Talent; Technology; Materials	1.Smart Interactive packaging for all (Real time info on Safety , nutrition, anti-littering & waste mgmt monitoring) 2. Smart Clothing - Regulatory framework updates, “Cultural Acceptance”, more customization & special applications. 3. Smart EE Community 4. Drug Delivery system through Smart Micro/Nano Packaging and Smart Medical Devices (Bio-based) widely used. 5. At least 50% population to have Smart Housing (Mass production, differentiation & cost performance based on target markets)

Table 7: Roadmap of the Plastic and Composites towards 2050 – Environmental and Sustainable Development

Focus Area	Short Term(2015-2020)	Medium Term(2021-2035)	Long Term(2036-2050)
Environmental and Sustainable Development or 3Ps i.e. Planet(Environment), People(Social), Prosperity(Economic)	1. Enhanced Education, Awareness Programs on 3Rs, waste management & Recycling Infrastructure 2. Holistic approach to sustainability 3. Adoption of LCA for products 4. Communicating the environment, safety and health 5. Effective post consumers plastics economy – From 3Rs, Waste to Wealth or Worth(W2W) & New Plastics(Circular) Economic 6 .Socially sustainable, safe and attractive workplaces 7. Reduce resource consumption and waste generation 8. Enhancement of Good relations & collaboration of academia – industry9 9. Establishment Research institute for National Composite Centre	1. Organic or Plastics photovoltaic cells may be the answer to at least 2 billion 'energy poor' people, living without access to electricity from the grid & people act as IPPs (Individual Power Producers). 2. Establishment Research institute for National Biomass. 3.Mass production of local products, technocrats, 4.Standards for materials with recycled and renewable content products in place 5.Mandatory laws & requirements on 3Rs, W2W and New Plastics Economy Fully practiced	1. Drug Delivery Smart Micro Packaging-Regulation and rule for new drug usage and control of drug release to environment 2. Industries such as Plastics & Composites, forestry and agriculture in harmony 3. Life style at par with the world 4. Energy & chemical feedstock independence including from 3Rs, W2W, New Plastics Economy, GHG, Biomass 5. 3Rs, W2W and New Plastics (Circular) Economy becomes a Culture & Mindset 6. Recovery of energy from household waste, Smart House policies in place

A very important and common themes or milestones in the above focused areas especially in the short term(2015-2020) is laying of the highly strategic “soft” and “hard” foundations or infrastructure (i.e. human and raw materials resources). On the former, it is crucial to first develop a quality and smart public and workforce to achieve the objectives of the Roadmap. These approaches are achievable in every organisation and at most levels in the short run, through increased training and understanding (particularly sustainable development), industrial learning, and proficiency enhancement programmes. These emphasise innovations and state-of-the-art technology, towards producing high value-added services and products that lessen reliance on foreign inputs.

While for the latter, short term, it is important to strengthen, expand product range and quickly initiate our position in key resins, commodities & substrates (i.e. PE, PP, PET, PC, PA, Epoxies & Biobased) production. On product development, short term, for example we need to further solidify and grow our current position in plastics packaging to higher end markets like “active” packaging. This is also to prepare for the onset of “Smart” packaging. In the case of specialty and high tech raw materials, currently with effectively zero production base, we need to jump start R&D and pilot production of nanomaterials (for e.g. graphene, nanotubes, long carbon fibres and etc.), conductive polymers, OLEDS, OFETS, self-healing polymers, etc. On product development, short term, a quick start is also needed in R&D for Smart Applications such as Packaging (initially RFID), E&E, housing, Transport and Clothing.

The bottom line, for short, medium & long term, in Roadmap construction is obviously funds, investment and money. This is critical especially in laying the above “soft” & “hard” foundation and building the pillars of the four focused area where the Return of Investment (ROI) may not be quick. Hence, the government, industries and key stakeholders need to enhance their partnerships, resolve and understanding on the need, short and long term benefits of such investments.

If the key roadmap themes and milestones for the short term (2015-2020), as discussed above, are to lay the “soft “and “hard” foundation. Then the medium term (2021-2035) ones are more about the “Convergence of Talents & Technologies” and “Carrots & Sticks” or Incentives & Laws especially to further instill the culture of the new Plastics Circular Economy.

On the former, current conventional or “passive” plastics packaging will converge with low cost printed plastics electronics and transistors to produce “Smart” or “Intelligent” packaging. These aforementioned technologies will also produce cheap organic (also called Roll-to-Roll or R2R) solar cells or photovoltaics based on plastics to replace conventional inorganic photovoltaics based on silicon and glass. Thus, Organic or Plastics photovoltaic cells may be the answer to at least 2 billion 'energy poor' people globally who currently are living without access to electricity from the grid (See Figure 55). Hence, by 2021 -2035 this R2R revolution will truly lead to “People’s Power” or people as Individual Power Producers (IPP).

Figure 55: Organic solar cells for off-grid use (Singh 2010)

The medium term will also see more “Voluntary to Mandatory” standards, “Carrots & Sticks” approaches especially for plastics waste management, 3Rs and Waste to Wealth (W2W) to further instill the culture of a Plastics Circular Economy.

The long term (2035-2050) scenario of the Roadmap have milestones and themes relating to “Smart & Sustainable High Quality of Life”, “Sustaining the Gain” and being“ A key World Class player”. By 2050, the Malaysian Plastics industry will be recognized as a key global player especially in Smart packaging targeting mainly the Food, Health and Hygiene markets, Smart E&E, Smart photovoltaics and Smart Clothing. While the Malaysian Composites industry will have the same global recognition especially in Smart Transport (for e.g. EEVs & UAVs) and Smart Housing using state-of-the Art technologies such as 3D & 4D printing. Also, the target of at least 50% the population living in affordable and comfortable Smart Homes is a noble and achievable milestone. More importantly, the Plastics Circular Economy will already be a culture, mindset and way of life in Malaysia by 2050.

The Roadmap also showed a “natural” and “familiar” path for Malaysia especially for Smart Applications and Industries. This is because currently we are already well established global players in E&E, Semiconductors, Plastics Packaging & Printing, Photovoltaics, LED, Automotive, Infrastructure, Clothing and Aerospace. Hence, the **Error!**

Reference source not found. shows the "chosen" path built from our present strength and legacy.

10.0 RECOMMENDATIONS

In Summary, the following Recommendations are proposed for the Plastics and Composites Sector:

i. To match the output of the Technical Vocational Education & Training (TVET) institutions with the manpower requirements of the plastics and composites industries.
ii. To endorse and fund industry association as plastics and composites Industry Steering Task Force (ISTF) under MITI
iii. To commit financial investment at par with advanced nations (2% of GDP) for research funding to be made available over the next 35 years
iv. To encourage all industries to use more plastics and polymer composites to improve performance and meet sustainability requirement (Life Cycle Assessment (LCA) and holistic approaches)
v. To encourage the plastics and composites industry and public sector to embrace the "Circular Economy" which include "Waste to Wealth or Worth (W2W)" and 3R (Reduce, Reuse, Recycle or Recover).
vi. The proposed new plastics economy is a broader more intensive version of the current "circular economy" or "waste to wealth or worth (W2W)" program for plastics practiced in some developed countries such as Sweden, Germany and Japan. Japan presently is the leader with an 82% recycling or recovery rate. The highest plastics recycling or recovery rate is for power and heat generation at 44%, followed by mechanical recycling at 22%, solid fuel for cement kilns at 13% and feedstock recycling at 3% (See Figure 56).

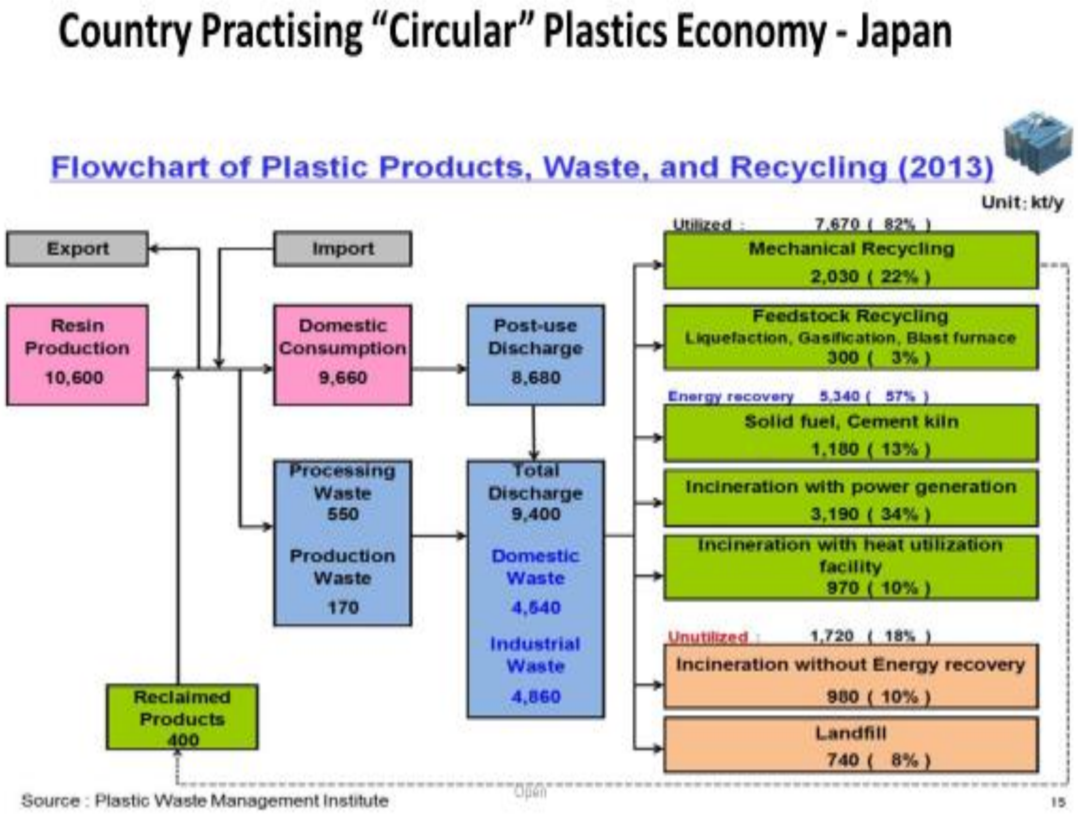

Figure 56: Flowchart of plastic product, waste and recycling

Japan began introducing the holistic approach to W2W and plastics circular economy in the late 1970's with simple waste sorting or separation at source for e.g. at homes. Now after 40 years, Japan is one of the cleanest, pollution and litter-free nations in the world.

Malaysians have begun progressing (1 September 2015) as the Japanese did four decades ago, when wastes separation was mandated at the source level through governmental mandate. Pursuant to the regulatory mandates of the Solid Waste and Public Cleansing Management Act of 2007 (Act 672), the scheme was first imposed in states and federal territories as follows: Kuala Lumpur, Johor, Putrajaya, Negeri Sembilan, Melaka, Kedah, Perlis, and Pahang. However, greater practice and collaboration, with added mandatory and incentives efforts, by all stakeholders are needed to make the new plastics circular economy a Malaysian culture and mindset by 2050.

Recommendation 3: Spearheading R&D in Advanced Plastics & Composite Materials

The MOSTI science outlook in 2015 reported that Malaysian gross expenditures in Research & Development per gross domestic product (GERD/GDP) increased from 0.5% in 2000 to 1.13% in 2012, although there is still a long journey ahead to the GERD/GDP objective of 2.0% by the year 2020. Research & development expenditures in the G20 group were 2.04% on average in 2012. Against this figure, Malaysian research & development expenditures are comparatively low. It is critical to consider that much research has demonstrated a direct association between investment levels in research & development, and rates of success in commercialisations. Nevertheless, it should be noted that research & development in terms of infrastructural and funding resources as well as human capital has to be appropriately employed to attain the desired results. The availability of fully-qualified and capable research scientists and technical specialists has been demonstrated to have considerably greater influence on output levels in comparison to the degree of expenditures on research & development.

R&D is undoubtedly an investment for our future; thus it should be at the heart of Malaysia’s blueprint for smart, sustainable and inclusive growth. The most critical element in building up the nation’s R&D capability is to develop a vast pool of world class leading scientists and researchers in the polymer and composites fields. One of the most important strategies will be to create a conducive environment to build, nurture and retain the much needed brainpower to open up new frontier in research excellence. The current reward system that gives the lion share to management carrier ladder and crumbs to researches is certainly not helpful and has to be revamped where excellent scientists need not migrate to management ladder for carrier progression. Although the dual ladder of progression has been promulgated and instituted in some organisations but in reality it is always adopting the management ladder tend to be the easier and more glamorous carrier path for Malaysian scientists. Unless and until this is remedied, the nation will never be able to build the critical mass of brilliant scientists required to spearhead R&D to secure more breakthroughs, discoveries and world-firsts.

After investment in manpower, the government should formulate generous R&D: ready to commit financial investment at par with advanced nations (2% of GDP) for research funding to be made available over the next 35 years. By coupling brains and Ringgit power, R&D and innovation of the nation will thrive and be synergised to result in world-class science and cutting edge researches creating tremendous impact to the Malaysian plastics and composites industries. As the main objective of the Mega Science Agenda is to provide key deliverables that include identification of STI opportunities and potential in the enhancement of plastics technologies, it would be most appropriate that this exercise will come up with frontier research direction that is able to provide total solution to the global plastics applications and implications. Advancement in plastics processing technology and its widespread usage as the material of choice in most packaging, have not come without its own perils.

"The new plastics economy - Rethinking the future of plastics" is recommended for modernisations to be pursued through real-world programmes that have the potential for high payoffs at larger scales. These innovative areas could comprise developments such as the evolution of biologically-benign resources, the evolution of materials synthesised to enable multi-layered reprocessing, i.e. reversible adhesive usage according to biomimicry discoveries, 'super polymers' that continue the functions of existing products but with enhanced recyclable properties, chemical marker techniques, as well as chemical-based recycling methods for overcoming certain ecological and economic costs in existing techniques.

The following is a summary of specific technological examples and their developmental maturities at present:

i. Innovative depolymerisations, i.e. reverting plastic materials to their monomer building block forms (feedstocks) for virgin-quality compounds – Innovations are presently in the laboratory phase and were shown to be technically feasible for polyolefin compounds.
ii. Developments in super-polymer compounds that merge existing functions with better after-use features – Presently in the conceptual phase, the difficulty lies in evolving cost-effective polymers with target functionality and after-use features.
iii. Removals of additive substances from recovered polymer compounds in order to raise the purities of recyclate materials – This is presently in the laboratory phase, with existing techniques and some constrained applications.
iv. Reversible adhesive substances that enable recyclable packaging made of multiple materials, allowing for activated separations of various layers of materials – This is presently in the conceptual phase as well, and much innovation is required to evolve cost-effective adhesive compounds.

v. Chemical marker substances that enable more efficient sorting methods for plastic materials through the use of inks, dyes, and other additive marker types that are identifiable via automated recognition technologies – This is presently in the pilot phase, wherein food-grade marker substances remain untested in commercial operations.

vi. Near-infrared technologies that assist more efficient sorting methods for plastic materials, through the use of automated optical recognition technologies that can discriminate between types of polymers – The present limited rate of adoption is due to the large initial capital expense involved.

vii. Benign behaviours in marine conditions by plastic materials designed to cause less harm in aquatic environments in the event of leakages – presently in the laboratory phase.

viii. Benign freshwater behaviours by plastic materials designed to cause less harm in freshwater environments in the event of leakages – presently in the pilot phase.

ix. GHG-based sourcing of plastic materials with consideration of carbon emissions by industry or waste management scheme – presently in the pilot phase.

x. Bio-input sourcing of plastic materials using carbons derived from production biomasses – presently limited in acceptance.

INNOVATION		DESCRIPTION	CURRENT STATE
	Removing additives	Separating additives from recovered polymers to increase recyclate purity	Lab stage: Some technologies exist but with limited application
	Reversible adhesives	Recycling multi-material packaging by designing 'reversible' adhesives that allow for triggered separation of different material layers	Conceptual stage: Innovation needed to develop cost-competitive adhesive
	Super-polymer	Finding a super-polymer that combines functionality and cost with superior after-use properties	Conceptual stage: Innovation needed to develop cost-competitive polymer with desired functional and after-use properties
	Depolymerisation	Recycling plastics to monomer feedstock (building blocks) for virgin-quality polymers	Lab stage: Proven technically possible for polyolefins Limited adoption: Large-scale adoption of depolymerisation for PET hindered by processing costs
	Chemical markers	Sorting plastics by using dye, ink or other additive markers detectable by automated sorting technology	Pilot stage: Food-grade markers available but unproven under commercial operating conditions
	Near infrared	Sorting plastics by using automated optical sorting technology to distinguish polymer types	Fragmented adoption: Large-scale adoption limited by capex demands
	Benign in marine environments	Design plastics that are less harmful to marine environments in case of leakage	Lab stage: First grades of marine degradable plastics (one avenue towards benign materials) already certified as marine degradable — impact of large-scale adoption to be proven
	Benign in fresh water	Design plastics that are less harmful to freshwater environments in case of leakage	Lab stage: Marine degradable plastics theoretically freshwater degradable. One certified product — impact of large-scale adoption to be proven
	GHG-based	Sourcing plastics from carbon in greenhouse gases released by industrial or waste management processes	Pilot stage: CO_2-based proven cost competitive in pilots; methane-based being scaled up to commercial volumes
	Bio-based	Sourcing plastics from carbon in biomass	Limited adoption: Large-scale adoption hindered by limited economies of scale and sophistication of global supply chains

Figure 57: Innovation and Current State (World Economic Forum 2016)

Summary of Proposed Strategies, Road Maps & Recommendations

i. Proposed Strategies

- Enhance innovation culture within the plastics and composites industry and business driven R&D by creating a conducive environment to build, nurture and retain the much needed brainpower to open up new frontier in research excellence. Strengthen and prioritise fundamental research to be the foundation for later developmental works. Subjects of interest should include:

  - Microelectronics (OLED, photovoltaic, transparent electronics/transistors)
  - Additive manufacturing (3D printing)
  - Advanced materials (Self-healing, lightweight materials, smart packaging, bio-based materials)
  - Environment and sustainability (Waste to Energy, micro irrigation, wastewater membrane filtration, off-grid desalination).

- Professional capacity and skills enhancement in plastic and composite materials
    - Successful academic-industrial-governmental triplex cooperation is vital to innovative thinking that engenders knowledge-intense sociocultures. To attain greater synergies, newer types of interactive communications are necessary to establish mutually enabling understandings among members.
    - The systematic organisation of different strategic programmes that recognise technological gaps and espouse "out-of-the-box" thinking
    - Increased participation of expert professionals at various phases and levels in R&TC value-added chains
    - To educate consumers on the benefits and responsibility dealing with plastics and composites materials
    - A more highly skilled workforce cab be built with Improved plastics and composites education and training.

- Manufacturers must be assisted in advancing the plastic and composite materials sector, with intense governmental encouragement.
    - Formation of ILB, industrial lead body that serve as the one stop centre for all innovation, R&D and business need of the industry
    - Support for the recognition of technological gaps across the industry and faster dissemination of primary technological advances

- Promotion of linkages across up-, mid-, and down-stream operations
    - To ensure sustainable and secure supply of key and strategic raw materials both commodities or substrates (for e.g. PE, PP, PET, PC, PA, Epoxies & Biobased) and specialties (for e.g. Nano materials such as Graphene, conductive polymers, long carbon fibres, self-healing polymers and etc.). Ideally both need to be locally produced especially the latter.

      Increased cross-border cooperation across industrial MNC, LLSC, and SME concerns – SME firms can acquire added-value advantages by working with proficient industry players in collaborative partnerships.

- To ensure sustainability of the plastics and composites industry via a circular economy approach.

- key policy makers to Engage and understand the needs of the Plastics and composites industry

ii. Recommendations (Short-Term, Medium-Term and Long-Term)

- To match the output of the Technical Vocational Education & Training (TVET) institutions with the manpower requirements of the plastics and composites industry.
- To endorse and fund industry association as Plastics and Composites Industry Steering Task Force (ISTF) under MITI
- To commit financial investment at par with advanced nations (2% of GDP) for research funding to be made available over the next 35 years
- To encourage all industries to use more plastics and polymer composites to improve performance and meet sustainability requirement (life cycle assessment (LCA) and holistic approaches)
- To ensure sustainable and secure local supply of major and strategic raw materials both commodities and specialties. It must include flexible and multi-source feedstocks and strong support especially from industries such as Oil & Gas, Petrochemicals, "Circular Economy" such as Waste Plastics Depolymerization or Chemical Recovery, Green House Gas(GHG) especially Methane & Carbon Dioxide from Household, Industrial, Municipal Wastes & landfills, Non Food based Biochemicals.
- To encourage the plastics and composites industry and public sector to embrace the "Circular Economy" which include "Waste to Wealth or Worth (W2W)" and 3R (Reduce, Reuse, Recycle or Recover).

11.0 TEAM MEMBERS

1. Prof. Zainal Arifin Mohd Ishak – Sectoral Leader
   (Universiti Sains Malaysia)
2. Mr. Ahmad Khairuddin Sha'aban - Expert
   (Malaysian Petrochemicals Association -MPA)
3. Mr. Mohd Fairus Ahmad - Expert
   (CTRM Aero Composites)
4. Mr. Eddie Fong Seak Foh - Expert
   (Malaysian Plastics Manufacturers Association -MPMA)
5. Dr. Ahmad Fuad Md. Yusof - Expert
   (SIRIM QAS International Sdn. Bhd)
6. Mr. Aminullah Ashari – Research Officer
   (SIRIM Bhd)
7. Mr. Mohd Zharif Ahmad Thirmizir – Research Officer
   (Universiti Sains Malaysia)

12.0 APPENDICES

MEGA SCIENCE AGENDA – MALAYSIA 2050 CONSULTIVE WORKSHOP (CENTRAL REGION)
[MEGA SCIENCE 3.0- PLASTICS AND COMPOSITES INDUSTRY SECTOR]

Function Hall , ASM, Kuala Lumpur
3rd JUNE 2015

Government Sector

No	Name	Organization
1	Datuk Dr. Hashim Wahab FASc	Academy of Sciences Malaysia (ASM)
2	Prof Dr C. C. Ho FASc	Academy of Sciences Malaysia (ASM)
3	Dr. Nur Aainaa Syafini binti Mohd Radzi	Nano Malaysia Berhad
4	Muhammad Fadhlullah bin Rahmat	Standards and Industrial Research Institute Of Malaysia (SIRIM)
5	Mr Yee Nai Tuck	Malaysian Investment Development Authority (MIDA)
6	Mr Wan Muhammad Shukri	Malaysian Investment Development Authority (MIDA)
7	Saiyidah Shahril Mohd Salleh	Malaysian Investment Development Authority (MIDA)
8	Mr Wan Mohd Hafizi Wan Hassin	Malaysian Automotive Institute (MAI)
9	Mr Sri Ram Letchimanan	Ministry of International Trade and Industry (MITI)
10	Mr Muhammad Razman A. Samah	Ministry of International Trade and Industry (MITI)
11	Prof. Ir. Dr. Sapuan Salit	Universiti Putra Malaysia (UPM)
12	Prof. Ir . Dr. Faizal Mustapha	Universiti Putra Malaysia (UPM)
13	Mohd Khairul Hafiz bin Muda	Universiti Putra Malaysia (UPM)

14	Mohd Na’im bin Abdullah	Universiti Putra Malaysia (UPM)
15	Mohd Saffuan bin Yaakob	Universiti Putra Malaysia (UPM)
16	Prof Dr Mat Uzir Wahit	Universiti Putra Malaysia (UPM)
17	Dr Chew Khoon Hee	Tunku Abdul Rahman University College (TAR UC)
18	Prof Dr Shahrim Bin Hj Ahmad	Universiti Kebangsaan Malaysia (UKM)
19	Jamari Abd Ghafar	Composites Technology Research Malaysia Sdn Bhd (CTRM)
20	Mohd Taufik Nordin	Composites Testing Laboratory Asia (CTLA)
21	Zulfadhli bin Idrus	Composites Testing Laboratory Asia (CTLA)
22	Mr Zamri Said	Petroliam Nasional Berhad (Petronas)
23	Mr Rozaimi Senawi	Innovative Pultrusion Sdn Bhd

Private Sector

No	Name	Organization
1	Mr Lye Kong Haw	Bold Vision Sdn Bhd
2	Mr Joseph Loh	Bold Vision Sdn Bhd
3	Dr . Loo Koi Sang	Malaysia Invention and Design Society (MINDS)
4	Ms Rusila Kamarulzaman	Everise Crimson (M) Sdn Bhd
5	Ms Maziah Mohamad	The Armour Factory Sdn Bhd

6	Mr Francis Valladares	Malaysian Plastics Manufacturers Association (MPMA)
7	Ms Sujata Albert	Malaysian Plastics Manufacturers Association (MPMA)
8	Mr Ng Kian Lin	Malaysian Plastics Manufacturers Association (MPMA)
9	Professor Dr Zahari Taha FASc	Universiti Malaysia Pahang (Sectoral leader – Furniture)
10	Dr Salwa Hanim Abdul Rashid	Universiti Malaya (Expert – Furniture)
11	Dr Muhizam Mustafa	Universiti Sains Malaysia (Expert – Creative)
12	Ms Amida Amaran	Malaysia Automotive Institute (MAI)
13	Ms Nurul Fateha Abd Aziz	Malaysia Automotive Institute (MAI)

MEGA SCIENCE AGENDA – MALAYSIA 2050 CONSULTIVE WORKSHOP (NORTHERN REGION)
[MEGA SCIENCE 3.0- PLASTICS AND COMPOSITES INDUSTRY SECTOR]

HOTEL BAYVIEW, GEORGETOWN, PENANG
30th SEPTEMBER 2015

Governments Sector

No	Name	Organization
1	Mr Muhammad Azizul Atli Adnan	Malaysian Investment Development Authority (MIDA), Penang
2	Mr Haslan Fadli Bin Ahmad Marzuki	SIRIM Berhad (AMREC)
3	Mr Engku Ahmadhilmi bin Engku Ubaidillah	SIRIM Berhad (AMREC)
4	Mr Mohd Fadzlee Zainal Abidin	SIRIM Berhad (AMREC)
5	Mr Leong Boon Yong	Northern Corridor Implementation Authority (NCIA)
6	Lt Kol (B) Dr. Zulkefli Ismail	Northern Corridor Implementation Authority (NCIA)
7	Mr Sukhairi Bin Samsudin	Jabatan Kimia Malaysia
8	Pn Suriai Binti Shaiddin	Jabatan Kimia Malaysia
9	Jansen Lim	MPWA (Northern Reg)
10	Dr. Zulkifli Mohamad Ariff	Universiti Sains Malaysia (USM)
11	Dr. Raa Khimi Shuib	Universiti Sains Malaysia (USM)
12	Dr Nik Noriman Bin Zulkepli	Universiti Malaysia Perlis (UNIMAP)
13	Dr. Sam Sung Ting	Universiti Malaysia Perlis (UNIMAP)

Private Sector

1	Yee Kole Leong	TORAY Malaysia
2	Ooi Choon Ping	TORAY Malaysia
3	Tam Wee Mui	DDI Sdn. Bhd.
4	Dr. Puan Yan	DDI Sdn. Bhd.
5	Mr Too Joon Kan	Pensia Plastic Sdn Bhd
6	Mr Saravanan a/l Muniandy	Pensia Plastic Sdn Bhd
7	Pn Nurziana binti Ishak	Heng Lee Composite Engeneering Sdn Bhd
8	Pn Ooi See Ling	Heng Lee Composite Engeneering Sdn Bhd

MEGA SCIENCE AGENDA – MALAYSIA 2050 CONSULTIVE WORKSHOP (EAST COAST REGION)
[MEGA SCIENCE 3.0- PLASTICS AND COMPOSITES INDUSTRY SECTOR]

THE M.S GARDEN HOTEL, KUANTAN
29TH OCTOBER 2015

Governments Sector

No	Name	Organization
1	Dr Mohamad bin Awang	Universiti Malaysia Terengganu
2	Dr Asmadi bin Ali @ Mahmud	Universiti Malaysia Terengganu
3	Dr Mohd AidilAdhha bin Abdullah	Universiti Malaysia Terengganu
4	Dr. Norhayati Abdullah	Universiti Malaysia Pahang
5	Dr Abd Aziz Mohd Azoddein	Universiti Malaysia Pahang
6	Mrs Siti Maznah binti Kabeb	Universiti Malaysia Pahang
7	Norhayati Nordin	Universiti Malaysia Pahang
8	Norhayati Nordin	Universiti Malaysia Pahang
9	Prof Dr Zahari Taha FASc	Universiti Malaysia Pahang

Private Sector

No	Name	Organization
1	Mr Shamsuddin bin Dato' Haji Musa	FM Plastics Indutries Sdn. Bhd.
2	Mr Salfaizwan Bin Salleh	Polymer Technologist Petronas Chemicals Ldpe Sdn. Bhd. (PC LDPE)
3	Shaiful Nizam Iskandar Mat Dali	Petronas Chemicals Innovation & Technology
4	Muhammad Fahmi Bin Azmi	Petronas Chemicals Innovation & Technology
5	Mohd Fairuz Bin Zainal Abidin	Petronas Chemical Polyethylene

MEGA SCIENCE AGENDA – MALAYSIA 2050 CONSULTIVE WORKSHOP (SABAH)
[MEGA SCIENCE 3.0- PLASTICS AND COMPOSITES INDUSTRY SECTOR]

PROMENADE HOTEL, KOTA KINABALU

8TH MARCH 2016

Governments Sector

No	Name	Organization
1	Mr Johny Yakin Sinit @ Yahya Bin Yakin	Politeknik Kota Kinabalu, Sabah
2	Mr Abdul Malek B. A. Manap	Politeknik Kota Kinabalu, Sabah
3	Mr Philips Dharmaraj	Politeknik Kota Kinabalu, Sabah
4	Mr Neilson Peter Sorimpuk	Politeknik Kota Kinabalu, Sabah
5	Mr Ajis bin Lepit	Uitm Sabah
6	Mrs. Julenah	Uitm Sabah
7	Dr Rahimatsah Amat FASc	Fellow Akademi Sains Malaysia

Private Sector

No	Name	Organization
1	Ms Chua Chiew Gee	Uniang Plastics Industry (Sabah) Sdn Bhd
2	Ms Kimberly Lim	Uniang Plastics Industry (Sabah) Sdn Bhd
3	Mr. Sai Jia Jin	Lok Kawi Plastics Industry Sdn Bhd
4	Mr. Sylvester Chua Yong Peng	Weida Integrated Industries Sdn Bhd
5	Reena Rahman	SIRIM QAS INT. Sdn Bhd

MEGA SCIENCE 3.0 – PLASTICS AND COMPOSITES INDUSTRY SECTOR (SARAWAK)

GRAND MARGHERITA HOTEL, KUCHING
10TH MARCH 2016

Governments Sector

No	Name	Organization
1	Puan Nancy Lai Siew Joon	Dept. Of Chemistry Malaysia, Kuching Branch
2	Puan Nirmala Bt Rabaie	Dept. Of Chemistry Malaysia, Kuching Branch
3	Mr John Melvin	Testing Executive SIRIM QAS International Sdn. Bhd
4	Dato' Dr Sim Soon Liang FASc	Fellow Akademi Sains Malaysia
5	Puan Nur Syuhada Bt Ahmad Zauzi	Universiti Malaysia Sarawak (UNIMAS)
6	Dr Md Rezaur Rahman	Universiti Malaysia Sarawak (UNIMAS)
7	Associate Prof. Dr Rubiyah Hj. Baini	Universiti Malaysia Sarawak (UNIMAS)
8	Dr Norsuzailina Bt Mohamed Sutan	Universiti Malaysia Sarawak (UNIMAS)
9	Ms Nur Amalina Shairah Bt Abdul Samat	Universiti Malaysia Sarawak (UNIMAS)
10	Mr Khairul Anwar B. Said	Universiti Malaysia Sarawak (UNIMAS)

Private Sector

No	Name	Organization
1	Mr Sun Nan Ping	General Manager Polyflow Pipes Sdn Bhd
2	Mr Ngu piew Hui	Director Kanma Plastic Material Sdn Bhd
3	Ms Evelyn Tang	Director Kanma Plastic Material Sdn Bhd
4	Mr Nicholas Kuan	Senior Lecturer Unimas
5	Prof Amir Azam Khan	UNIMAS
6	Josephine Lai Chang Hui	UNIMAS
7	Linna Chieng	Sarawak Forestry Corporation

MEGA SCIENCE 3.0 – PLASTICS AND COMPOSITES INDUSTRY SECTOR (SOUTHERN REGION)

PERSADA JOHOR INTERNATIONAL CONVENTION CENTRE, JOHOR BAHRU 31ST MARCH 2016

Government Sector

No	Name	Organization
1	Dr Agus bin Arsad	Senior Lecturer UTM-MPRC Institute for Oil and Gas (UTM-MPRC) Faculty of Chemical and Energy Engineering Universiti Teknologi Malaysia
2	Dr. Zurina Binti Mohamad	Assoc. Prof/ Lecturer Universiti Teknologi Malaysia
3	Mr Ahmad Ramli Rashidi	Faculty Of Chemical Engineering, UiTM Johor, Pasir Gudang Campus
4	Ms. Arbanah Muhammad	Faculty Of Chemical Engineering, UiTM Johor, Pasir Gudang Campus
5	Mr. Mohd Haikal Mustafa	Faculty Of Chemical Engineering, UiTM Johor, Pasir Gudang Campus
6	Dr Nadia Adrus	Polymer Engineering Department Faculty of Chemical and Energy Engineering Universiti Teknologi Malaysia
7	Prof Dr Azman Hassan	Polymer Engineering Department Faculty of Chemical and Energy Engineering Universiti Teknologi Malaysia
8	Dr Reza Arjmandi	Polymer Engineering Department Faculty of Chemical and Energy Engineering Universiti Teknologi Malaysia
9	Prof Dr Mat Uzir Mahit	Polymer Engineering Department Faculty of Chemical and Energy Engineering Universiti Teknologi Malaysia

Private Sector

No	Name	Organization
1	Ms Beno Seow	Director Business Development Dynaglass Advanced Composite Sdn. Bhd
2	Mr Terisss Chooi	General Manager Development Dynaglass Advanced Composite Sdn. Bhd
3	Mr Ho min Seang	Lotte Chemical Titan (M) Sdn Bhd.
4	Mr Chin Soo Hean	Lotte Chemical Titan (M) Sdn Bhd.

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