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CHEMICAL ENGINEERING IN MALAYSIA – INDUSTRY OUTLOOK AND EDUCATION PERSPECTIVE

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Malaysia is a country that is blessed with variety of natural resources. During the British colonial time in the early 20th century, tin mine and rubber industrial sectors formed the backbone of Peninsular Malaya's economics. The collapse of natural rubber price in the 70s then witnessed the growth of the oil palm plantation in the country. The country then shifted its agriculture-based economy towards manufacturing after the 80s, mainly focusing on computers and electronic products. The 90s mark the important milestone for Malaysian chemical industry, as many major chemical plants were commissioned in the country. Due to its rich natural resources, most of these plants are petrochemical- and oleochemical-based. Since then, both of these industrial sectors contribute significantly to Malaysia economics.

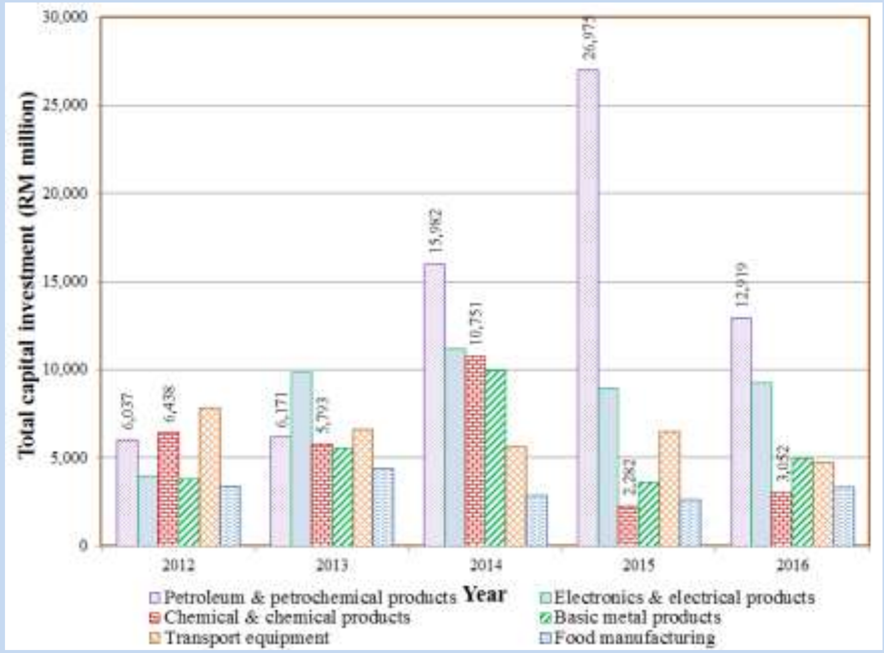

Figure 1. Total capital investment for major approved manufacturing projects in Malaysia (MIDA, 2017)

Part of this article were extracted from previous works of the author – Foo (2015a, 2015b).

Upcoming Conferences and Events

Date	Conference and Event	Venue
2 – 6 October 2017	10th World Congress of Chemical Engineering (WCCE)	Barcelona, Spain
12 – 13 Sept 2017	4th CCPS Global Summit on Process Safety	Okayama, Japan
15 – 16 Nov 2017	24th Regional Symposium on Chemical Engineering (RSCE 2018)	Semarang, Indonesia
13 – 15 Mar 2018	Society of Chemical Engineers Japan (SCEJ) Annual Meeting	Kansai University, Osaka
1 – 5 July 2018	Process Systems Engineering (PSE 2018)	San Diego, US
1 – 2 Aug 2018	4th international Conference of Chemical Engineering and Industrial Biotechnology (ICCEIB 2018)	Kuala Lumpur, Malaysia
30 Sept – 3 Oct 2018	47th CHEMECA	Queenstown, New Zealand
28 Oct – 2 Nov 2018	2018 AIChE Annual Meeting	Pittsburgh, US
23 – 27 Sept 2019	18th Asia Pacific Confederation of Chemical Engineers Congress	Sapporo, Japan

Overview of Malaysian manufacturing sectors: investments and trades

Over the past decade, capital investment for Malaysian manufacturing sectors has been growing steadily. **Figure 1** shows the six major sectors that have attracted the most capital investment between years 2012 – 2016. In this period, the petroleum and petrochemical products sector attracted the most investment, i.e. RM 68.1 Million (approximately USD 16.2 million, with exchange rate of 1 USD: 4.2 RM), followed by the chemical & chemical products sector (RM 28.3 Million), and transport equipment (RM 14.5 Million). The investment in the petroleum and petrochemical products sector is mainly due to the PETRONAS' Refinery and Petrochemical Integrated Development – RAPID project (see discussion that follows).

In term of trades, electrical & electronic products contribute the most to country's economics, as they are the major export goods from Malaysia (see **Figure 2**). This is followed by chemicals and chemical products, petroleum products, palm oil, etc. Malaysia also imported significant amount of electrical & electronic products, followed by chemicals and chemical products, machinery and equipment parts, petroleum products, etc. (**Figure 3**).

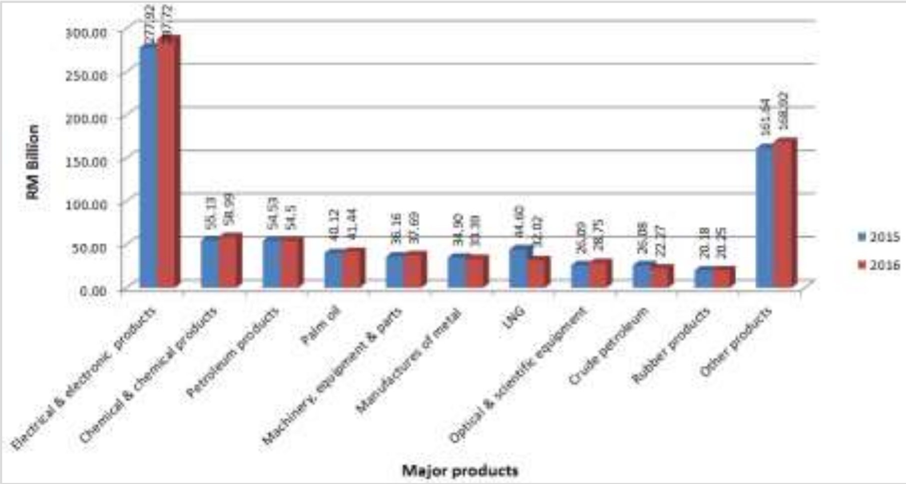

Figure 2. Major export products in Malaysia (MATRADE, 2017)

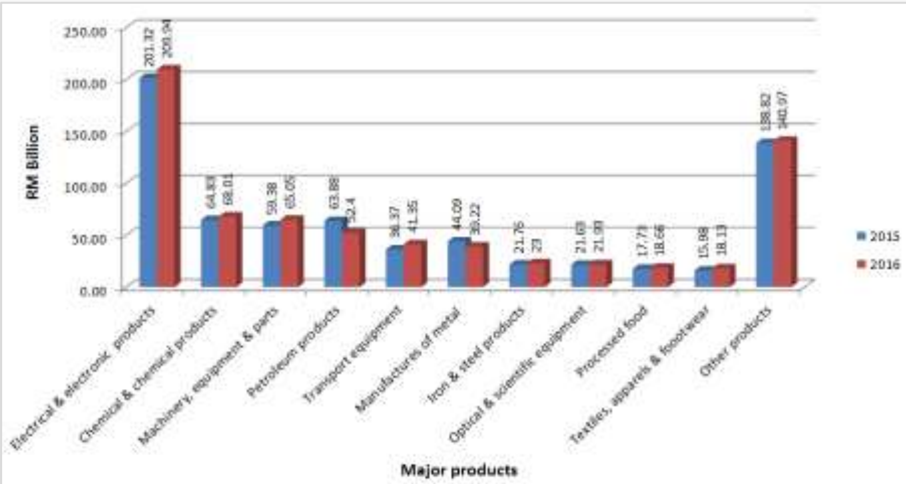

Figure 3. Major import products in Malaysia (MATRADE, 2017)

Malaysia is an open economy with a small domestic market. Hence, Malaysian businesses are encouraged to expand beyond the country border. To assist companies for product export, Malaysian government has signed and implemented 7 bilateral free trade agreements (FTA) and 6 regional FTAs with ASEAN Free Trade Agreement (AFTA). For 2016, the FTA partner countries contributed 62.3% of Malaysia's total exports (RM490.1 billion) (MITI, 2017).

Oil & gas (O&G), and petrochemical industry

Even though crude oil was discovered as early as 1910 in the Borneo island, and the first crude oil refinery was constructed in 1914 (Royal Dutch Shell, 2016), the O&G industry does not seem to contribute significantly to the national economics prior to the 70s. An important milestone for the Malaysian O&G industry was the incorporation of the national oil company, i.e. Petroliam Nasional Berhad – PETRONAS under the Petroleum Development Act (PDA), 1974. Under the PDA, PETRONAS has entire ownership and rights to explore and produce O&G resources in Malaysia. Expenditure and profits are managed through the Production Sharing Contracts (PSCs). To date, more than 150 PSCs have been awarded to approximately 30 contractors (The Star, 2013). In year 2012, the O&G industry contributes approximately 20% to national gross domestic product (GDP), providing approximately 20,000 job opportunities (**Figure 4**).

The three main products of this industrial sectors include the natural gas, petroleum products (e.g. gasoline, kerosene, fuel oils, liquefied petroleum gas, naphtha, etc.); and various petrochemical products. Malaysia is ranked 28 for its proven oil reserve, and the 16 for its gas reserve (MPA, 2016). Malaysia is the world's second largest exporter of liquefied natural gas (LNG) and has the world's largest production facility at a single location (located at Bintulu) with production capacity of 25.7 million MT per year (MPA, 2016). The *Peninsular Gas Utilization* (PGU) project initiated in 1984 was an important milestone for the gas sector. With the completion of PGU project in 1998, approximately 2 billion standard cubic feet (MMSCF) of processed natural gas is sent from six gas processing plants (GPPs) in the east coast of Peninsular Malaysia to various power, industrial and commercial sectors in the country through PGU pipeline network (see **Figure 5**). Malaysia has forged partnerships with other ASEAN countries, e.g. Vietnam, Indonesia and the Malaysia-Thailand Joint Development Area (JDA) for secure gas supply (MPA, 2016). On the other hand, the main petroleum products are mainly produced by the by the six crude oil refineries in the country (the same producers for naphtha feedstocks in **Table 3**).

Figure 4. Contribution of PSCs for Malaysia (The Star, 2013)

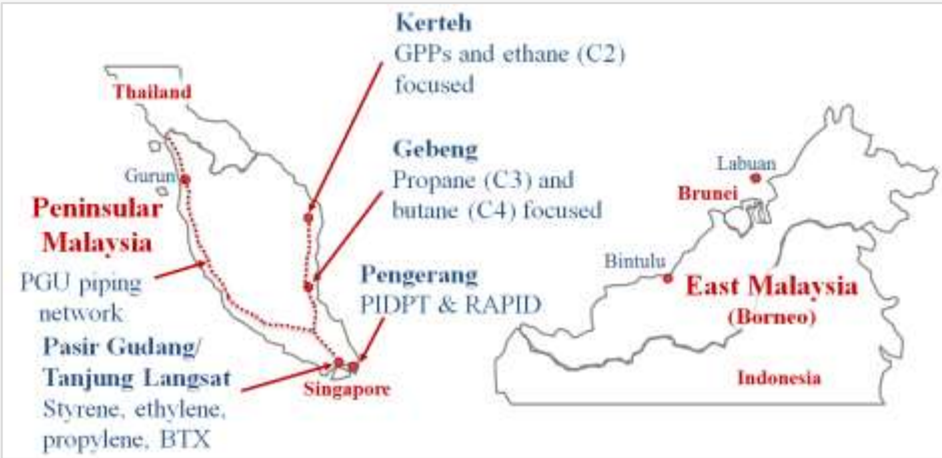

Figure 5. Major petrochemical hubs in Malaysia

If 1970s is considered the oil era for Malaysia, and 1980s as the gas era, then the 1990s would be considered as the petrochemical era for Malaysia. The main reasons for the growth include availability of feedstock, well-developed infrastructure (including the PGU project), and strong base of supporting services. Many world renowned petrochemical companies (e.g. Kaneka, Polyplastic, BP, Shell, BASF, etc.) established their production plants in Malaysia in the 1990s. Three major petrochemical hubs have then been established in Malaysia, i.e. Kertih (Terengganu state), Gebeng (Pahang state), and Pasir Gudang/Tanjung Langsat (Johor state). Apart from these hubs, petrochemical plants are also found in other cities such as Labuan (methanol), Gurun (urea), Bintulu (ammonia, urea), etc. (see **Figure 5** for location). Malaysia produces and exports a wide range of petrochemical feedstocks, e.g. olefins, polyolefins, aromatics, ethylene oxides, glycols, oxo-alcohols, acrylic acids, phthalic anhydride, acetic acid, styrene monomer in are summarized in **Table 3**. The world scale production of these petrochemical feedstocks also ensures steady supply of feedstock material for the downstream plastic industry. Besides, some special chemicals production has just been initiated at BASF PETRONAS Chemicals (Gebeng), i.e. citral, citronellol and L-menthol; 2-ethylhexanoic acid; and highly reactive poly-isobutene (MPA, 2016).

Table 3. Important petrochemical feedstock producers in Malaysia (MIDA, 2013)

Petrochemical feedstock	Capacity	Producers
Naphtha	611,000 [bbl/day]	Petronas Penapisan (Terengganu) Petronas Penapisan (Melaka) Malaysia Refinery Company Hengyuan Refinery Company Petron Malaysia Refining & Marketing Kemaman Bitumen Company
Methane, ethane, propane, butane condensate, liquefied petroleum gas (LPG)	42.16 million MT/y	Petronas Gas Malaysia LNG MLNG Dua MLNG Tiga
Ethylene	1.22 million MT/y	Lotte Chemical Titan Holding Petronas Chemical Ethylene Petronas Chemical Olefins
Propylene	955 thousand MT/y	Lotte Chemical Titan Holding Petronas Chemical MTBE Petronas Chemical Olefins
Benzene, toluene, xylene (BTX)	888 thousand MT/y	Lotte Chemical Titan Holding Petronas Chemical Aromatics

A new petrochemical zone under development currently is the Pengerang Integrated Petroleum Complex (PIPC), which is planned to be operational by 2019. The PIPC occupies a single plot of land of approximately 20,000 acres. The project will house oil refineries, naphtha crackers, petrochemical plants as well as a LNG import terminals and a regasification plant. Two major catalytic projects committed within the PIPC are the US$3 billion Pengerang Deepwater Terminal (PDT) and US$16 billion Refinery and Petrochemical Integrated Development (RAPID) Project (with another US$11 billion in investment for its associated facilities). The PDT is a joint-venture between Malaysian DIALOG Group and Johor State Secretary Incorporated, and Royal Vopak of Netherlands. The RAPID will have refining capacity of 300,000 bbl/day (JPDC, 2017), with additional petrochemical plants that will produce a total of 3.15 million MT/y of specialty polymers and glycols (MPA, 2016). The completion of the RAPID project in 2019 will soon contribute to the wider spectrum of petrochemical products of the country.

The growth of the O&G industry has also spawned its associated support industry that provides services and products to the various operational companies. The growth of many new engineering services companies have been seen since the 90s (Mohamad Razalli, 2005; Candiah, 2005). After two decades of development, Malaysia is now the regional center for design and engineering services for the O&G sector. Estimation shows that there are over 3,500 O&G businesses in Malaysia (MIDA, 2015), comprising of international oil companies, independents, services and manufacturing companies that support the needs of the O&G value chain both domestically and regionally. These companies consist of many national and international machinery and equipment manufacturers, as well as those that provide services in the area of marine engineering, drilling, engineering, fabrication, offshore installation, as well as operations and maintenance (MIDA, 2015). The main reason of this significant growth is cost and quality. Even though other countries in this region can also provide low cost services, many international clients still prefer Malaysian companies due to its high quality work, and the availability of up-to-date technological knowledge. Besides, developed infrastructure, supportive government policies, ease of doing business, O&G resources availability, quality of life at affordable price are among advantages that make Malaysia competitive in the O&G engineering services (MPRC, 2017).

Due to the low oil price, many O&G service providers are working hard to sustain business growth in the past two years. One of the main efforts for survival including the PETRONAS-driven Cost Reduction Alliance – CORAL 2.0 (IEM, 2016). Besides, lack of research and development (R&D) initiative is also a well known fact in the O&G sector. This is unlike the electrical and electronic sectors where R&D activities are an integral component of their operations (MPA, 2016). To stay competitive, the O&G giant – Petronas partners with world leading technological providers in its operation and production activities. Moving forward, Malaysia government aims to position Malaysia to be the most important O&G hub in the Asia Pacific region within the current decade (MPRC, 2017).

Palm oil-based oleochemical industry

Oil palm was originated from West Africa, and was planted in Peninsular Malaysia as earlier as 1917 (MPOC, 2016). Signification growth for the plantation area was observed in the 70s, following the collapse of the global price of rubber (which was the main agricultural output of Malaysia). Many palm oil refineries were also set up about the same period, in response to government's call for increased industrialization (MPOC, 2016). To date, Malaysia is the world's second largest (after Indonesia) producer of crude palm oil (CPO). In 2016, the country has planted area of 5.74 (as compared to 5.64 million hectares in 2015), which leads to the CPO production of 17.32 million MT (a decline from year 2015 at 19.96 million MT) (MPOB, 2017). Total exports of oil palm products (palm oil, palm kernel oil, palm kernel cake) are reported at 23.29 million MT in 2016 (decline as compared to 25.37 million MT in 2015). However, due to higher export prices, the total export revenue increased to RM 64.59 billion (as compared to RM 60.17 billion in 2015). The three main export markets for Malaysian palm oil are India (2.83 million MT, 17.6% of total palm oil exports), European Union (EU, 2.06 million MT, 12.8%), and China (1.88 million MT, 11.7%) (MPOB, 2017). On the other hand, EU was the major export market for palm kernel oil (0.25 million MT, 26.6%), followed by China (0.13 million MT, 14.3%) and USA (0.13 million MT, 13.9%). For palm kernel cake, the major export markets were EU (0.68 million MT, 30.6%), and New Zealand (0.53 million MT, 23.9%) (MPOB, 2017).

The establishment of palm oil refineries in the 70s is an important step for this industrial sectors, as it marked the production of a wide range of palm oil products, ranging from edible oils to various raw materials for oleochemicals production, e.g. palm kernel oil, palm stearin, palm kernel fatty acids distillate. This boosted the expansion of the Malaysian oleochemical industry in the 80s, apart from the government incentives. To date, there are 18 oleochemical companies in Malaysia, with global player such as IOI, Emery, KL-Kepong, etc. (**Figure 6**), producing raw material for various manufacturing industries such as food, pharmaceuticals, cosmetics and detergents. Malaysia is now the largest oleochemical producer in the world, accounting for approximately 20% of the global capacity (MIDA, 2014). Almost all oleochemicals produced in Malaysia are exported. In year 2016, export of oleochemical products decreased slightly to 2.76 million MT (from 2.85 million MT in year 2015), with the major markets being EU (0.53 million MT, 19.2% of total oleochemical exports), followed by China (0.39 million MT, 14.2%), USA (0.27 million MT, 9.6%) and Japan (0.23 million MT, 8.5%) (MPOB, 2017). As shown in **Figure 7**, the major oleochemical products exported were fatty acids, methyl ester, fatty alcohol, soap noodles and glycerine. **Figure 8** shows the global oleochemical production, in which Asia being the main producer. Within Asia, the Southeast Asia region (SEA – mainly Malaysia and Indonesia) account for 65% of the total production.

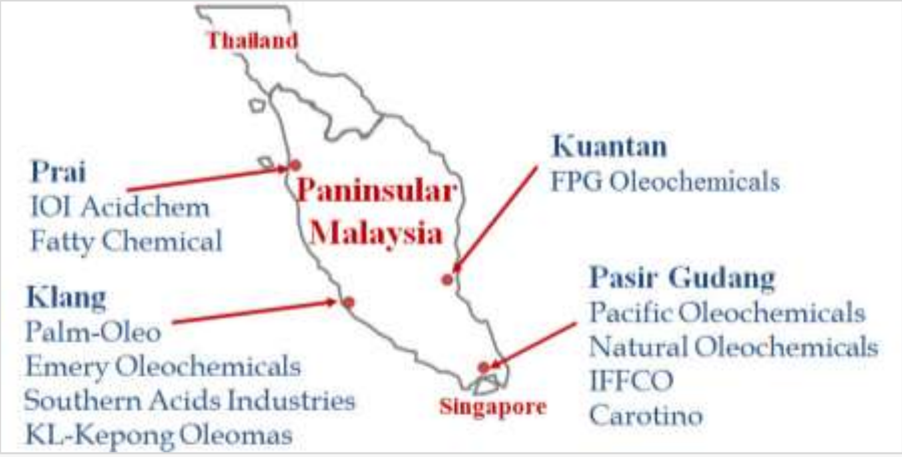

Figure 6. Some of the major oleochemical plants in Malaysia

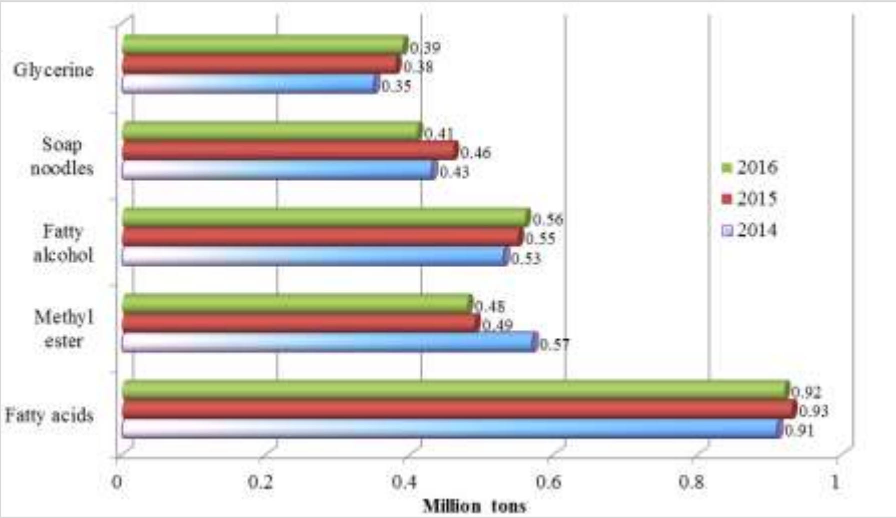

Figure 7. Export of Malaysian oleochemical products (MPOB, 2016, 2017)

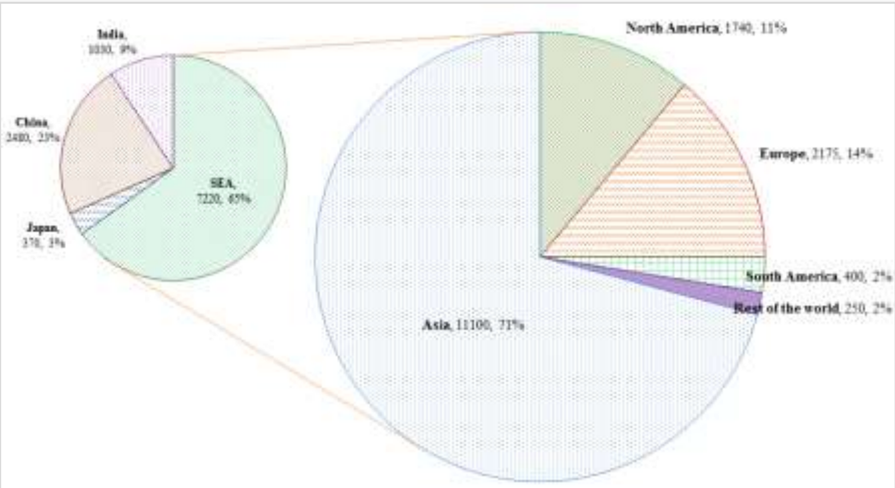

Figure 8. Global oleochemical production (x1000 tonnes) by region for year 2013 (MIDA, 2014)

It is worth noting that due to recent trend in sustainability development, demands for safer and biodegradable products are on the rise. Hence, palm-based oleochemical products have gained good attention in recent years due to its ability in replacing the conventional petroleum-based products. The emerging sectors where the oleochemicals may be utilized as specialty chemicals are lubricants, polymers, and surfactants (Panchal et al., 2017). The biodegradable nature of bio-lubricants makes it a strong substitute for petroleum-based lubricants. Similarly, biopolymers may also substitute the traditional petrochemicals-based polymers due to their bio-degradability. In the surfactants sector, the oleochemical-based Methyl Ether Sulfonate (MES) is a potential substitute for petroleum-based Linear Alkyl Benzene Sulfonate (LABS). By year 2020, the MES is expected to cover a global market of 1.2 million MT, i.e. replacing one third of the LABS demand (Panchal et al., 2017).

Besides, it is also worth noting that in the past few years, palm-based biomass has gained good attention in the industry as well as research community. The palm oil industry is the main sector that produces the most biomass in Malaysia. The National Biomass Strategy (NBS) 2020 was launched in year 2011 and administered by the National Innovation Agency Malaysia (AIM, 2017). NBS lays the foundations for Malaysia to capitalize on its biomass by channeling it into higher value downstream uses. In 2012, Malaysia's palm oil industry produced over 83 million MT of dry solid biomass. This volume is projected to increase to 85–110 million MT by year 2020. On the other hand, the volumes of palm oil mill effluent (POME) are expected to increase from 60 million MT today to 70–110 million MT by 2020. Most of the solid biomass is found in the plantations, as oil palm fronds (OPF) and trunks (OPT) account for approximately 75% of the solid biomass volume, while the remaining is waste generated from palm oil milling processes. Study shows that approximately 25 million MT of dry biomass could be aggregated at competitive cost (less than RM 250/MT) (AIM, 2017). Two main technological pathways may be used to convert the palm biomass into higher value-added products such as bioethanol and bio-based chemicals, i.e. OPF juice and lignocellulosic pathways (**Figure 9**). However, the technologies are yet to reach a mature stage for full commercialization. To fully capitalise on the biomass opportunity, the biomass could be deployed towards higher value downstream activities such as pellets, bioethanol and bio-based chemicals (AIM, 2017). Converting biomass to pellets allow the biomass owners to ship its pellets to other Asian countries such as Japan and Korea. For bioethanol, there is increasing evidence that the second generation bioethanol market will be mature, with commercial plants established and over 700 million liters worldwide. Bio-based chemicals are identified being the largest potential for Malaysia. The global market for lignocellulosic biomass is estimated with market size of RM 48 billion, which is expected to grow to as RM 110–175 billion by year 2020. Malaysia can produce as much as 1.6 million MT of biobased chemicals, with a market value of RM 7–9 billion (AIM, 2017).

Figure 9. Two main pathways for utilising palm-based biomasses (AIM, 2017)

Chemical engineering education

Earlier sections of the report discussed about the boost of the CPI in Malaysia in 1990s, when many major petrochemical and oleochemical plants were commissioned, which then lead to significant increase of career opportunities for chemical engineering (ChE) graduates. This also led to the exponential increase of ChE Departments as well as number of graduates in the country. A survey conducted in 2014 (Foo, 2015b) revealed that, there are over 20 universities that offer ChE-related programs in Malaysia, with a total of approximately 2400 ChE graduates in 2014 (see **Figure 9** and details in **Table 3**). One can easily observe that, approximately one new ChE programme is offered annually among Malaysian universities for the last two decades (i.e. 1995 – 2014), despite the fact that it involves high capital expenditure (mainly due to expensive teaching and learning facilities including laboratory set-up). Note also that foreign university branches offer some of these programmes in Malaysia, including those from UK, Australia and China. Most of the undergraduate programs are accredited by the Engineering Accreditation Council (EAC) of the Board of Engineers Malaysia; while a few by the Institute of Chemical Engineers (IChemE) and Engineers Australia (IEAust). As Malaysia was accepted as the 13th signatory of the Washington Accord on 18th June 2009 (EAC, 2010), all graduates from EAC-accredited programs after June 2009 are by default recognized by the signatories of the Washington accord. In other words, a Malaysian ChE graduate from an EAC-accredited program fulfils the minimum requirements of ABET (US), and is able to sit for the Professional Engineering (PEng) examination in the US.

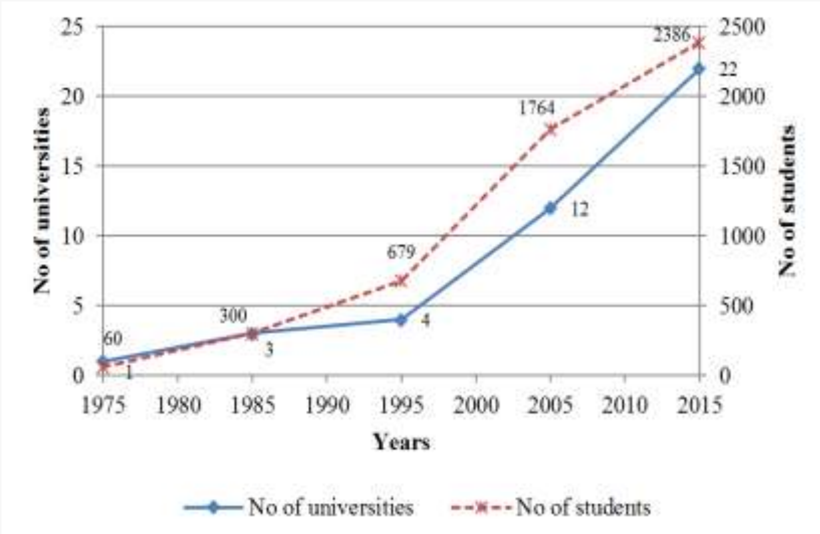

Figure 9. Numbers of universities with ChE programmes and undergraduate students in Malaysia (Foo, 2015b)

Table 3. Chemical engineering programmes in Malaysia (Foo, 2015b)

Name of institution	Date started	Annual intake	Accreditation bodies
1. University Malaya (UM)	1974	60	EAC, IChemE
2. Universiti Teknologi Malaysia (UTM)	1983	160	EAC
3. National University of Malaysia (UKM)	1984	80	EAC
4. Universiti Sains Malaysia (USM)	1992	70	EAC, IChemE
5. Universiti Putra Malaysia (UPM)	1996	59	EAC
6. Universiti Teknologi Petronas (UTP)	1997	190	EAC
7. Universiti Malaysia Sabah (UMS)	1998	75	EAC
8. Curtin University, Sarawak Malaysia	2000	100	EAC, IChemE, IEAust
9. Universiti Kuala Lumpur (UniKL-MICET)	2006	400	EAC
10. Universiti Malaysia Pahang (UMP)	2002	120	EAC
11. Universiti Teknologi MARA (UiTM)	2000	270	EAC
12. University of Nottingham (UNMC)	2003	130	EAC, IChemE
13. Universiti Malaysia Perlis (UniMAP)	2005	50	
14. Monash University Malaysia (MUM)	2006	100	EAC, IEAust
15. Universiti Tunku Abdul Rahman (UTAR)	2006	150	EAC
16. UCSI University (UCSI)	2008	93	EAC
17. Universiti Malaysia Sarawak (UNIMAS)	2009	80	EAC
18. Taylor's University	2009	70	EAC
19. Manipal International University (MIU)	2012	80	EAC
20. Swinburne University of Technology Sarawak Campus	2012	25	EAC
21. Universiti Tun Hussein Onn Malaysia (UTHM)	2012	30	
22. Heriot-Watt University Malaysia Campus (HWUM)	2014	60	IChemE, EAC
23. Manipal International University Nilai Campus*	2015		
24. Xiamen University Malaysia Campus*	2016		

* New programmes since 2015

Professional bodies and trade organizations

Needless to say, professional bodies and trade organizations play important role in fostering positive development for the chemical industry in Malaysia. Among all, the Institution of Engineers Malaysia (IEM; see logo in **Figure 10(a)**) is the biggest professional body in Malaysia, with a total membership of approximately 30,000. IEM was established in 1959 (i.e. 2 years after independence of Malaysia), with the aim to promote the engineering profession in the country (IEM, 2017). Within IEM, the Chemical Engineering Technical Division (CETD) plays an important role in promoting interaction among working professionals and academics. One of the most important annual events of CETD is the Malaysian Chem-E-Car competition, which has been held for a decade. The Chem-E-Car event sees the participation of many Malaysian chemical engineering undergraduate students, with the aim to encourage the development of new energy sources. Besides, CETD also organized the national Chemical Engineering Design Competition and Research Paper Competition in recent years (IEM, 2013). CETD also assist the Board of Engineer Malaysia (BEM) to conduct Professional Interview, where passed candidates will be awarded the Professional Engineer (PEng) status. CETD also represents IEM in the Asia Pacific Confederation of Chemical Engineering (APCChE).

Another important professional body is the Institution of Chemical Engineers (IChemE; see logo in **Figure 10(b)**) that started the Malaysia Branch since 2006 (IChemE, 2017), as a continuation of the Institution of Chemical Engineers Malaysia (IChEM). One of the main activities of IChemE Malaysia Branch is the annual research conference known as the Symposium of Malaysian Chemical Engineers (SOMChE), as well as the bi-annual Hazards Asia Pacific process safety symposium. IChemE also host the annual meeting of the undergraduate students, i.e. National Chemical Engineering Symposium (NACES), in which various competitions (e.g. design project, technical presentation, etc.) are held.

Another important organization is the Chemical Industries Council of Malaysia (CICM; see logo in **Figure 10(c)**) that was originally established as an industry group within the Federation of Malaysian Manufacturers (FMM) in 1978. CICM established its separate legal entity since 1982, in response to the growth of the chemical industry (CICM, 2015). CICM has more than 100 members, comprising of manufacturers, traders, distributors and servicing companies. It promotes the co-operation among chemical companies as well as the development of the chemical industry in the country. It also represents Malaysia in the ASEAN Chemical Industries Council (ACIC). One of the important initiative of CICM is the encouragement on continuous improvement of health, safety and environmental performance through their Responsible Care Program that was launched since 1994 (CICM, 2015). Other important industrial-specific organizations in Malaysia include the Malaysian Gas Association (MGA), Malaysian Petrochemicals Association (MPA). Malaysian Oil and Gas Engineering Council (MOGEC). Malaysian Oleochemical Manufacturers Group (MOMG), Malaysian Palm Oil Council (MPOC), Malaysian Plastics Manufacturers Association (MPMA), etc.

(a) (b) (c)

Figure 10. Important professional bodies and trade organization in Malaysia: (a) IEM; (b) IChemE; (c) CICM

Looking forward

The chemical industry in Malaysia has been on its rise for the past decades. The O&G and petrochemicals as well as the palm oil-based oleochemical sectors will remain as the main industrial sectors that contribute to the country economy for the coming decades. This also strengthens the growth of Malaysia chemical engineering community as a whole, and will witness Malaysia to emerge as a major leader in chemical engineering and chemical industry for the Asia Pacific region in the coming years.

Acknowledgement

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References

Agensi Inovasi Malaysia (AIM, 2017). www.nbs2020.gov.my (access June 2017).
Candiah, R.G. (2005). Malaysia as a Regional Hub for Oil and Gas Engineering Services. *JURUTERA*. January 2005, Institution of Engineers Malaysia.
Chemical Industries Council of Malaysia (CICM, 2015). www.cicm.org.my (accessed March 2015).
Engineering Accreditation Council (EAC) (2010). http://www.eac.org.my. (accessed Sept 2017).
Foo, D. C. Y. (2015a). The Malaysian Chemicals Industry: From Commodities to Manufacturing. *Chemical Engineering Progress*. 111(10): 48-52 (November 2015).
Foo, D. C. Y. (2015b). Chemical Engineering Education in Malaysia. *JURUTERA*, 2015(9): 36-38 (September 2015).
Institution of Chemical Engineers (IChemE, 2017). www.icheme.org/malaysia (accessed Sept 2017).
Institution of Engineers Malaysia (IEM, 2013). *JURUTERA*. September 2013.
Institution of Engineers Malaysia (IEM, 2016). CORAL 2.0 for Long Term Survival. *JURUTERA*. November 2016.
Institution of Engineers Malaysia (IEM, 2017). www.myiem.org.my (accessed July 2017).
Johor Petroleum Development Corporation (JPDC, 2017). Pengerang Integrated Petroleum Complex (PIPC). http://www.jpdc.gov.my/development/pipc/ (accessed June 2017).
Malaysia External Trade Development Corporation (MATRADE, 2017). http://www.matrade.gov.my (accessed June 2017).
Malaysian Investment Development Authority (MIDA, 2013). *Profit from Malaysia's Petrochemical Industry*.

Malaysian Investment Development Authority (MIDA, 2014). Seminar on Oleochemical Industry In Malaysia: Downstream Expansion & Sustainability.
Malaysian Investment Development Authority (MIDA, 2015). Oil and Gas. www.mida.gov.my/home/oil-and-gas/posts/ (accessed Feb 2015).
Malaysian Investment Development Authority (MIDA, 2017). *Malaysia Investment Performance Report (2012*, *2013*, *2014*, *2015*, *2016)*. www.mida.gov.my (accessed July 2017).
Ministry of International Trade and Industry (MITI, 2017). Malaysia's Free Trade Agreements. http://fta.miti.gov.my (accessed June 2017).
Malaysian Petrochemicals Association (MPA, 2016). *Malaysia Petrochemical Country Report 2015*. Presented at The Asia Petrochemical Industry Conference, Singapore.
Malaysian Palm Oil Board (MPOB, 2016). Overview of the Malaysian Oil Palm Industry 2015.
Malaysian Palm Oil Board (MPOB, 2017). Overview of the Malaysian Oil Palm Industry 2016.
Malaysian Palm Oil Council (MPOC, 2016). www.mpoc.org.my (accessed April 2016).
Malaysia Petroleum Resources Corporation (MPRC, 2017). Why Malaysia. www.mprc.gov.my (access June 2017).
Mohamad Razalli, R. (2005). The Malaysian Oil and Gas Industry: An Overview. *JURUTERA*, January 2005.
Panchal, M., Kapoor, C. and Agrawal, B. (2017). Oleochemicals gaining prominence in speciality chemicals. TATA Strategic Management Group. www.tsmg.com (access June 2017).
Royal Dutch Shell (2016). The History of Shell in Malaysia. http://www.shell.com.my/aboutshell/who-we-are/history/malaysia.html (access April 2016)
The Star (2013). Malaysia has 100 Active Oil Production Sharing Contract, Highest Ever. www.thestar.com.my (accessed Feb 2015)

Biography

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