CHEMICAL ENGINEERING TRANSACTIONS
VOL. 72, 2019
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Jeng Shiun Lim, Azizul Azri Mustaffa, Nur Nabila Abdul Hamid, Jiří Jaromír Klemeš

ISBN 978-88-95608-69-3; **ISSN** 2283-9216
DOI: 10.3303/CET1972045

Energy Demand and GHG Emissions by 2030: A Scenario Analysis Using Extended Snapshot Tool towards Sustainable Low Carbon Emissions Development in Pengerang

Muhammad Akmal Hakim Hishammuddin[a], Gabriel Hoh Teck Ling[a,*], Loon Wai Chau[a], Ahmad Muzammil Idris[b], Wai Shin Ho[b], Chin Siong Ho[a], Chew Tin Lee[c]

[a]UTM-Low Carbon Asia Research Centre (UTM-LCARC), Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia UTM, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Process Systems Engineering Centre (PROSPECT), School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor Bahru, Johor Darul Takzim, Malaysia
[c]School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor Bahru, Johor Darul Takzim, Malaysia
gabriel.ling@utm.my

Pengerang, Johor, Malaysia is to become at global centre of integrated petrochemical refinery industry under the Malaysia's National Key Economic Area (NKEA) and will become the largest regional petroleum refinery and trading hub in South East Asia. In line with the national aims towards carbon neutrality, Pengerang is set to achieve as much as 50 % carbon emission reduction towards its Clean, Green, Safe and Smart Pengerang vision by 2030. This paper is performed based on the baseline results of the energy supply and demand scenario in Pengerang from base year 2010 until targeted year of 2030. The scenario is modelled using the Extended Snapshot (ExSS) tool by using the Kaya Identity equation (human population, Gross Domestic Products (GDP) per capita and energy intensity). The data assumption for the model is based on best practice low carbon emissions port city such as Rotterdam. The model estimates about 691 % carbon emission increment from 2010 to 2030 without low carbon emissions countermeasures (CM) in Pengerang, due to expected rapid development lead by the petroleum refining and petrochemical industries in the area. Future renewable energy supply (e.g. biomass, biogas, solar) and demand is plugged into the model to portray the low carbon emissions scenario that Pengerang could establish by 2030. This paper concludes, Pengerang can potentially achieve as much as 50 % carbon emission reduction in 2030 CM scenario, through increased energy efficiency of industries and alternative energy resources application.

1. Pengerang key profile

Pengerang, Johor, Malaysia has been planned to become the global centre for integrated petrochemical refinery industry under the Malaysia's National Key Economic Area (NKEA). With an area of 1,288.3 km^2 and total population of 86,632 in 2010, it is targeted to place the largest regional petroleum refinery and trading hub in the South East Asia (SEA) by 2020. Located in the Southern Eastern tip of Peninsular Malaysia, the area has merely over 1,321 million RM in GDP. Over the years, it has seen an increase of investments and development over the past few years sourced from the Pengerang Integrated Petroleum Complex (PIPC) project. With its strategic location of shipping lanes from the Middle East- Singapore – China and adjacent to the SEA's logistic tycoon, Singapore, PIPC will be a big step in creating value for the downstream oil and gas industry via petrochemical refining facility in Johor and Malaysia. Based on Rancangan Tempatan Daerah Kota Tinggi 2020, Pengerang 2010 land use comprises of agriculture (palm oil and rubber), aquaculture, forestry, water bodies (including river), seashore, hinterland, transportation, and industries, residential (e.g. local villages (Federal Land Development Authority (FELDA) settlements, rural areas and the new uprising township developments), public facilities, open space and recreational area, commercials and lastly, infrastructure and utilities (see Figure 1 and Table 1)

Paper Received: 23 April 2018; Revised: 27 August 2018; Accepted: 22 November 2018

Please cite this article as: Hakim Hishammuddin M.A., Ling G.H.T., Chau L.W., Idris A.M., Ho W.S., Ho C.S., Lee C.T., 2019, Energy demand and ghg emissions by 2030: a scenario analysis using extended snapshot tool towards sustainable low carbon development in pengerang, Chemical Engineering Transactions, 72, 265-270 DOI:10.3303/CET1972045

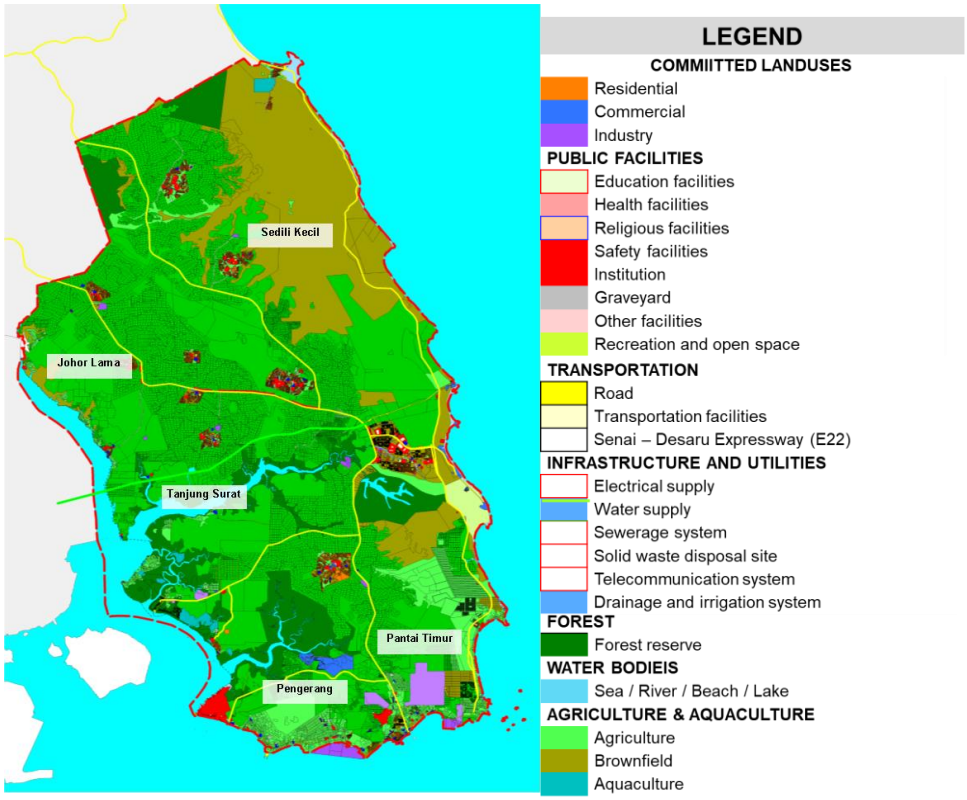

Figure 1: Land use map of Pengerang, Johor, Malaysia

Table 1: Pengerang Land Use 2010

Land use	Area (ha)	%
Residential	1,586.82	1.23
Commercial	643.98	0.50
Industry	1,601.45	1.24
Recreation and open space	852.51	0.66
Public facilities	858.67	0.67
Infrastructure and utilities	239.10	0.19
Transportation	4,191.34	3.25
Forest	11,651.31	9.04
Agriculture and aquaculture	101,196.09	78.55
Water bodies (including river)	6,008.74	4.66
Total	128,830.00	100

In 2010, the agriculture and aquaculture land use in Pengerang held the highest proportion of total land area, which accounts to 101,196.09 ha (78.55 %). This is followed by forestry at 9.04 %, and the rest of other land uses. Industrial land uses was just 1.24 %.

In conjunction with the PIPC industry which will sets for its full operation in 2020, Pengerang GDP is expected to grow at a rate of 11% per capita per y from 2010 until 2030. The GDP share change of primary industries such as agriculture and aquaculture is expected to reduce as much as 80 % while other manufacturing industries such as PIPC will increase from 1.2 % to 66 %. Thus, Pengerang will have to take smart low carbon emissions measures as this type of industry will consume extensive energy and face tremendous pressure on energy sustainability (Kangying et al., 2016). Using the ExSS quantification tool, Pengerang can determine its strength and suitable low carbon emissions countermeasures to ensure that it will be able to achieve its Clean, Green, Safe and Smart Pengerang vision by 2030 by reducing its carbon emission footprint in line with the nation targets to achieve carbon neutrality.

2. Extended snapshot (ExSS) tool

This study uses the ExSS tool along with other GHG emission models such as solid waste, agriculture and carbon sink to quantify the Pengerang GHG emissions. ExSS is a key component of the Asia-Pacific Integrated Model (AIM) developed by Kyoto University and National Institute for Environmental Studies (NIES), Japan and approved by the Intergovernmental Panel on Climate Change (IPCC) as a recognised modelling methodology (Zakri Abdul, 2017).

It is a modelling tool to assess the future energy consumption, power generation, technology diffusion, transportation, industrial outputs, residential and commercial activities, waste generation and GHG emissions, coupling with predetermined socioeconomic, industrial and demographic scenarios in a particular future or target year (Gomi et al., 2010). It comprises of four modules; 1) driving forces (population and GDP), 2) energy service demand (energy consumption), 3) primary energy supply and 4) GHG emissions. It is expressed in the form of Kaya Identity Eq(1):

$$F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} \quad (1)$$

F is the GHG or carbon dioxide (CO_2) emissions from human sources, *P* is population, *G* is GDP and *E* is energy consumption (PennState Department of Meteorology, 2015). The GDP and energy consumption of the sectors in baseline year 2010 such as residential, commercial, transportation, industry, waste, agriculture and carbon sink are input into the ExSS software based on available government statistic data online. Using this basic equation of Kaya Identity, this study has produced the baseline results based on the aforementioned driving force in the Kaya Identity equation.

3. Pengerang's energy baseline results 2010 and 2030 scenario

3.1 Scenario assumptions

Appropriate assumptions are also used where information for macroeconomic analysis is not available (Ho et al., 2010). Most of the socio-economic and input data where synthesised from the national energy balance table, obtained from official documents and secondary sources. Assumptions used in the energy quantification of Pengerang by 2030 can be referred in Table 2 (Adapted from Toshihiko, 2015).

Table 2: Assumptions for Pengerang energy scenario by 2030

Sector	Low carbon emissions society scenario
Summary	Petrochemical industry development will grow triple by the year 2030, Potential energy efficiency improvement for industries
Economy	Average growth rate of GDP/year due to the petrochemical industry development: 17%. Benchmarked on average development growth rate of petrochemical cities best practices such as Rotterdam, Kaohsiung, Gothenburg and Chiba, GDP growth rate/capita/year: 11%
Population	Total population in 2030 is expected to be 252,771 with 5.50% average increase rate of population per year
Transportation	Increase use of public transport such as bus and reduction of private vehicles to, 55:45
Commercial Buildings	40% diffusion of building passive design and 5% solar power generation
Industries	Increased 10% efficiency for industrial operation Optimum resource Clean energy (15% biomass and 20% solar)
Carbon sink	Increased and preserved urban fringe and forestry area
Behaviour & Lifestyle	Energy saving action (10% improvement)
Education	Low carbon emissions education to youth and community
Waste	Higher 25% recycling rate through 3R programme Resource circulatory Circular economy
Governance	Efficiency will be improved accordingly
Land use	Speedier and more efficient land use change

3.2 Energy demand

Based on the assumptions, the energy demand by power supply results is achieved. Figure 2 shows the result of 2030 Business as Usual (BaU) scenario, where there are no low carbon emissions countermeasures taken, the natural gas supply is expected to increase from 57 ktoe to 7,842 ktoe. Oil is also expected to increase high from 53 ktoe to 848 ktoe. Nevertheless, in 2030 CM, this scenario can be lowered with the introduction of renewable energy such as 15 % of biogas, palm oil mill effluent (POME) and 20 % of solar energy in Pengerang.

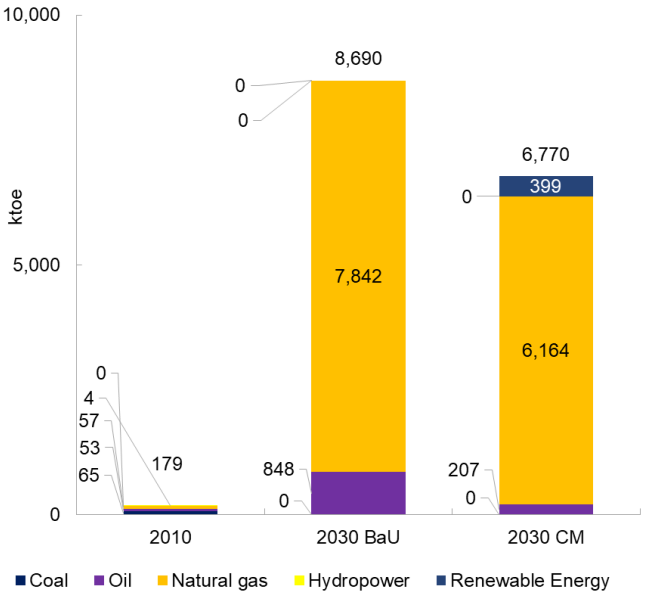

Figure 2: Pengerang energy demand by energy source

3.3 Final energy demand by sector

Based on Table 3, in 2030 BaU scenario, industry sector is expected to be the primary consumer of energy with 5,935 ktoe followed by passenger transport at 269 ktoe and freight transport 260 ktoe, commercials consumes as much as 435 ktoe while residential is the least at 79 ktoe. However, these sectors has a potential of decrease in energy consumption as much as 1 4% with countermeasures identified in 2030 CM scenario.

Table 3: Final energy demand by sector

Sector	Energy demand (ktoe)		
	2010	2030 BaU	2030 CM
Residential	19	79	69
Commercial	14	435	368
Industry	10	5,935	5,252
Passenger transport	35	260	89
Freight transport	5	269	181
Total	83	6,978	5,959

3.4 GHG emissions by end-use sector

Based on Figure 3, in 2030 BaU scenario, the model estimates that the total GHG emissions by end-use sector in Pengerang will increase about 691 % from 2010, this is due to the rapid industrialisation and development lead by the petrochemical refineries hub in the area. Nevertheless, Pengerang can potentially achieve as much as 50% carbon emission reduction in 2030 CM scenario in comparison with 2030 BaU scenario through decreased emission in the sectors of industry, transportation, commercials and an increased potential value of carbon sink.

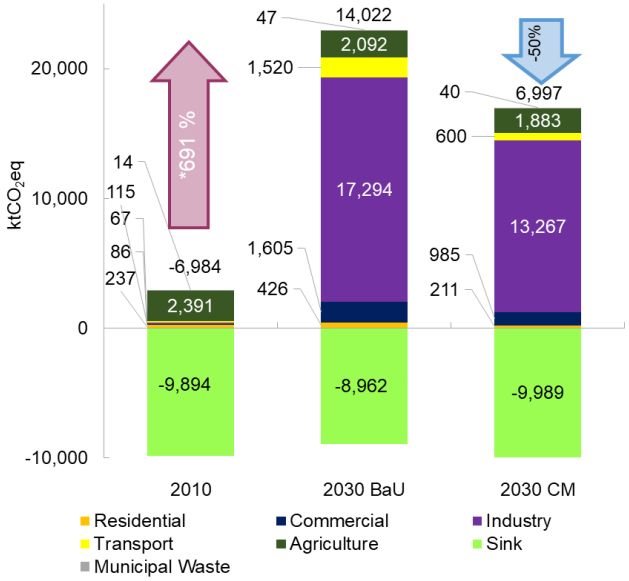

Figure 3: Pengerang GHG emissions by end-use sector

4. Conclusions and suggestions

With the quantified potential of 50 % carbon emissions reduction by 2030 for Pengerang, 10 Key Actions have been proposed as low carbon emissions countermeasures to be taken by the Pengerang Local Authority, stakeholders as well as communities of Pengerang. The 10 Actions are divided to the Triple Bottom Line (TBL) of Economy, Environment and Social with Green Urban Governance acts as an enabler. The 10 Key Actions and quantified values of GHG reduction by the countermeasures are shown in in Table 4.

Table 4: 10 Key Actions and quantified values of GHG reduction

Action	GHG reduction (kt CO_2-eq)	%	TBL
1. Decarbonising Industries	794	12	
2. Smart Tourism	298	4	
3. Smart Agriculture	269	4	Economy (45 %)
4. Sustainable Energy System	1,313	19	
5. Green Mobility	438	6	
6. Low Carbon emissions Urban Settlements	969	14	
7. Sustainable Waste Management	395	6	Environment (35 %)
8. Blue and Green Network	1,027	15	
9. Low Carbon emissions Smart Community	1,339	20	Social (20 %)
10. Green Urban Governance	-	0	
Total	6,840	100	100

Pengerang can achieve its 50 % carbon emission by 2030 through extensive future renewable or alternative resources as energy supply (e.g. biomass, biogas, solar) and demand is plugged into the model to portray the low carbon emissions scenario that Pengerang could potentially achieve by 2030. Increased efficiency in the industry as much as 10% and smart energy management system also contribute to a very significant reduction of carbon emission followed by carbon sink. Towards reducing the resource consumption such as energy and water in the industrial processing plants in Pengerang, waste and resource circulation or Circular Economy (CE) concept can be introduced in the industry by reusing wastewater via complex water treatment plant back into the initial loop and converting the released stream of CO_2 to the potential power supply or energy (Muhammad Akmal Hakim et al., 2018). Pengerang can potentially reduce its targeted 50% carbon emission by implementing these countermeasures by 2030. Petroleum refining enterprises should make full use of opportunities as alternative fuel consumption will display an upward trend in future.

Acknowledgments

Authors would like to express gratitude to the research members of UTM-Low Carbon Asia Research Centre (UTM-LCARC), PROSPECT and E-Konzal for the useful input and not to be forgotten, the Pengerang Local Authority for their invaluable support.

References

Gemeente Rotterdam, 2017, Roadmap circular economy Rotterdam, Rotterdam Make It Happen, City of Rotterdam, Netherlands.

Gomi K., Shimada K., Matsuoka Y., 2010, A low-carbon scenario creation method for a local-scale economy and its application in Kyoto City, Energy Policy, 38, 4783–4796.

Ho C.S., Ibrahim I., Joeman B.D., Muhammad Hussein M.Z.S, Chau L.W., Matsuoka Y., Kurata G., Fujiwara T., Shimada K., Gomi K., Yoshimoto K., Simson J.J., 2010, Low-Carbon City 2025: Sustainable Iskandar Malaysia, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

JPDC (Johor Petroleum Development Corporation Berhad), 2016, JPDC oil & gas projects in Johor, Johor Petroleum Development Corporation Berhad (JPDC), Oil & Gas Projects in Johor <www.jpdc.gov.myf> accessed 26.04.2016.

Kangyin D., Renjin S., Hongdian J., Hui L., 2016, Integrated evaluation of circular economy method for chinese petroleum refining industry, Oxidation Communications 39, No. 4-IV, 3999–4013 (2016), School of Business Administration, China University of Petroleum-Beijing, China.

MPRC (Malaysia Petroleum Resources Corporation), 2017, Pengerang integrated petroleum complex (pipc) <www.mprc.gov.my> accessed 24.09.2017.

Hishammuddin M.A.H., Gabriel L.H.T, Chau L.W., Ho C.S., Ho W.S., Idris A.M., 2018, Circular economy (CE): a framework towards sustainable low carbon development in Pengerang, Johor, Malaysia, Chemical Engineering Transactions, 63, 481-486.

National Institute for Environmental Studies, 2015, Structure of extended snapshot (ExSS) tool <https://ebrary.net/15272/environment/structure_extended_snapshot_exss_tool> accessed 14.05.2018.

PennState Department of Meteorology, 2015, The Kaya Identity, meteo 469, from Meteorology to Mitigation: Understanding Global Warming <e-education.psu.edu/meteo469/node/213> accessed 27.11.2015.

Shahizatul F., 2017, PBT, UTM Pengerang meterai MoU, Karangkraf Group Media <sinarharian.com.my/edisi/johor/pbt-utm-pengerang-meterai-mou-1.712526> accessed 21.09.2017.

Toshihiko M., 2015, Contribution of AIM (asia-pacific integrated model to indcs in Asia, National Institute for Environmental Studies <env.go.jp/earth/ondanka/attach_8/3_1_ToshihikoMasui.pdf> accessed 14.05.2018.

Town and Country Planning Johor, 2016, Rancangan tempatan daerah Kota Tinggi 2020, Johor, Malaysia.

Wei Z., 2017, Construction and stability studies on industrial chain network of circular economy of organic chemical industry, Chemical Engineering Transactions, 62, 1507-1512.

Zakri A.H, 2017, Towards a carbon-neutral Malaysia by 2050, new straits times, excerpted from a keynote address to the 3rd International Conference of Low Carbon Asia and Beyond, Nov 1-3, Bangkok <nst.com.my/opinion/columnists/2017/11/302480/towards-carbon-neutral-malaysia-2050>accessed 14.05.2017.