SLUDGE MANAGEMENT OPTIONS FOR ENERGY RECOVERY USING INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE GUIDELINES

NAWAL BINTI SHAHARUDDIN

A thesis submitted in fulfilment of the
Requirements for the award of the degree of
Master of Engineering (Environment)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

OCTOBER 2016

“ Kerana sesungguhnya sesudah kesulitan, ada kemudahan…

Sesungguhnya sesudah kesulitan ada kemudahan…”

(Al-Insyirah: 5-6)

ACKNOWLEDGEMENTS

First and foremost, my deepest appreciation to Prof Dr Mohd Razman Bin Salim and Dr Salmiati for their supervision. I could not have accomplished this research without their expert advice and opinions.

I offer my regards and blessings to all my beloved friends in Institut Pengurusan Alam Sekitar dan Sumber Air (IPASA) and Low Carbon Society (LCS) miss Azilah, Anis, Tan, Teh, Abu, Nadzirah, Cindy, Okabe-san, Hatanaka-san, and Suda-san. I extend my appreciation and thanks to my colleagues and friends who stands firmly behind me.

I am indebted with Japan International Cooperation Agency (JICA), for the given opportunity to run this research. As well the experience given in working with exceptional staffs.

Not forgetting, my family, Ayah and Ibu, Kak Long, Kak Ngah, Hanis, Khadijah and Muaz, for their constant support as well my husband, Ahmad. I would like to express my love for their understanding and blessing

ABSTRACT

Treatment and disposal of sewage sludge generate considerable amounts of methane gas (CH_4) and have the potential to pose environmental challenges to wastewater treatment. In recent years, the level of awareness on climate change issue in Malaysia has been raised. In support of this action, Iskandar Malaysia (IM) is selected as an eco-friendly city. The selection of sludge management strategies is crucial because various combinations of treatment technologies and disposal methods exhibit different emission rates. To achieve sustainable sludge management, this study aims to investigate and compare two different scenarios for mitigation of methane gas (CH_4) using 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines. These scenarios involve landfill, incineration, beneficial use, anaerobic digestion and composting. In order to observe the differences in CH_4 gas emission and solid reduction, baseline studies were applied within a period of time (2005-2025) with two different scenarios (business as usual, BaU and counter measure, CM). The year 2025 was chosen as the target years based on IM Comprehensive Development Plan 2025. The BaU scenario represents the current sludge management (SM) without mitigation measures. The CM scenario represents SM with mitigation measures, which includes anaerobic digestion, incineration, composting, landfill and its beneficial use. The use of IPCC method assists the quantification process, based on the calculation of emission factor times activity data calculation. The study areas included sewage treatment plants (STP) located in IM. The current SM in IM uses dewatering and landfill as the disposal options, which consists of drying beds (DB), pond desilting, mechanical sludge treatment (belt filter press and centrifuge system), desludging tanker, and Geobag. The results show that both scenarios present a significant reduction of solids. The BaU scenario offers up to 38.5% potential for solid reduction in the sludge. While the CM scenario offers up to 67.3% of the solid reduction in the sludge by 2025. In BaU scenario, a total of 114,582 tons of solids is estimated to be disposed to the landfill by 2025. However, by applying the mitigation option, an estimated 2,292 tons of solids will be disposed to landfill by 2025. This is about 98% reduction of solids sent to the landfill. The current CH_4 emission is approximately 32 Gg CH_4 under the BaU scenario and estimated to increase to 37 Gg CH_4 by 2025. With the CM scenario, the CH_4 emission can be decreased to 77% or to 28.4 Gg CH_4/year. The anaerobic digestion can serve as the treatment option to generate up to 62 Gg CH_4. There is an increase of energy up to 71% from the treatment category, while 64% of energy increases in overall. By 2025, an estimated amount of 8.6 Gg CH_4/year is released under the CM scenario. However, under the BaU scenario without any mitigation measures, 37 Gg CH_4 /year was estimated to be released into the atmosphere by 2025.

ABSTRAK

Proses rawatan dan pelupusan enapcemar menghasilkan gas metana (CH_4) yang berpotensi untuk menjejaskan alam sekitar, terutamanya dalam proses merawat air sisa kumbahan. Pada masa kini, tahap kesedaran dalam menangani perubahan iklim semakin meningkat di Malaysia. Iskandar Malaysia (IM) telah dipilih sebagai bandar mesra alam sebagai tanda menyokong tindakan ini. Pemilihan strategi pengurusan enapcemar adalah penting kerana gabungan teknologi rawatan dan kaedah pelupusan enapcemar yang berbeza akan menghasilkan kadar pelepasan gas yang berbeza. Untuk mencapai pengurusan enapcemar yang mapan, kajian ini bertujuan untuk mengkaji dan membandingkan perbezaan pelepasan gas CH_4 di dalam dua senario pengurusan enapcemar berdasarkan 2006 *Intergovernmental Panel on Climate Change*. Senario-senario tersebut melibatkan tapak pelupusan, pembakaran, kegunaan berfaedah, pencernaan anaerobik dan pengkomposan. Untuk melihat perbezaan pelepasan gas dan pengurangan pepejal, kajian garis dasar dijalankan dalam tempoh masa tertentu (2005-2025) bagi dua senario yang berbeza (seperti biasa, BaU dan langkah pengurangan, CM). Tahun 2025 telah dipilih berdasarkan Rancangan Pembangunan Komprehensif IM 2025. Senario BaU merupakan senario pengurusan enapcemar tanpa langkah pengurangan, manakala senario CM mempunyai langkah pengurangan (pencernaan anaerobik, pembakaran, pengkomposan, tapak pelupusan dan kegunaan berfaedah). Garis panduan IPCC 2006 digunakan dalam proses kuantifikasi iaitu pengiraan faktor pelepasan didarab dengan data aktiviti. Loji-loji rawatan kumbahan (STP) di IM dipilih sebagai kawasan kajian. Sistem pengurusan enapcemar semasa di loji-loji ini adalah penyahairan dan tapak pelupusan. Teknologi penyahairan terdiri daripada *drying beds* (DB), pengeluaran kelodak kolam, rawatan enapcemar secara mekanikal (*belt filter press* dan system emparan), pengosongan tangki, dan *Geobag*. Hasil keputusan menunjukkan terdapat pengurangan pepejal yang ketara melalui dua senario ini. Sebanyak 38.5% pepejal dapat dikurangkan jika senario BaU dipilih. Namun begitu, sebanyak 67.3% pepejal dapat dikurangkan melalui senario CM. Selain itu, dianggarkan sebanyak 114,582 tan pepejal akan dilupuskan pada tahun 2025 dengan senario BaU. Walau bagaimanapun, dengan memilih CM, hanya 2,292 tan pepejal dianggarkan akan dilupuskan pada tahun 2025. Pengurangan sebanyak 98% pepejal yang dihantar ke tapak pelupusan dilihat dapat dilakukan. Pelepasan gas CH_4 semasa adalah 32 Gg CH_4. Jika senario BaU dipilih, pelepasan gas CH_4 akan meningkat sehingga 37 Gg CH_4. Sebaliknya, jika senario CM dipilih, pelepasan gas akan menurun sehingga 77% dengan 28.4 Gg CH_4. AD sebagai rawatan pilihan berpotensi untuk menjana 62 Gg CH_4. Kenaikan tenaga sebanyak 71% dicatatkan bagi kategori rawatan, manakala peningkatan sebanyak 64% dianggarkan secara keseluruhan. Menjelang 2025, dianggarkan sebanyak 8.6 Gg CH_4 akan dilepaskan dalam senario CM. Walau bagaimanapun, jika senario BaU dipilih tanpa sebarang langkah pengurangan, dianggarkan sebanyak 37 Gg CH_4 akan dilepaskan ke atmosfera.

TABLE CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

BaU	Business as Usual
CH_4	Methane
CM	Counter Measure
CO_2	Carbon Dioxide
CO_2 Eq	Carbon Dioxide Equivalent
FiT	Feed in Tariff
Gg	Giga Gram
GHG	Green House Gas
IM	Iskandar Malaysia
IWK	Indah Water Konsortium
N_2O	Nitrous Oxide
SM	Sludge Management
STP	Sludge Treatment Plants
SWM	Solid Waste Management
WWTP	Waste water Treatment Plant

LIST OF SYMBOLS

m^3	cubic meter
Gg	giga gram
kg	kilogram

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Problem

In December 2010, Prime Minister Najib Razak made a bold statement before the whole world regarding Malaysia's commitment to lessen up to 40% of carbon emission intensity with respect to gross development production (GDP) by 2020. The announcement was made during COP 15 that was held in Copenhagen (Siong, 2013). This commitment could be made possible with financial help—obviously—from developed countries. Central to this is the proposed Renewable Energy Act. This challenge has provided opportunities for Malaysians to investigate future emissions from various sectors as well as Malaysia's renewable energy from different sources and emissions, including potential energy recovery from sewage sludge in Malaysia (Veerannan, 2011). It is perceived that the management of wastewater sludge is a standout amongst the most discriminating ecological issues because of the quick increment in sludge production as an aftereffect of sewerage augmentation, new establishments, and improvements of existing facilities (Ujang and Salmiati, 2011). Sludge is created under distinctive technical, financial, and social settings, hence obliging diverse methodologies and different solutions for an ideal management procedure (Spinosa, 2011).

As the amount of sludge generated continuously increases, and with the rising awareness, it has become necessary to include considerations on energy and resource consumption, costs, normative and legal requirements, as well as public acceptance (Abu-Orf *et al.,* 2011). The rapid increase in sludge production has additionally brought to light the rising concern in the sludge final disposal: landfill. Tighter and more stringent laws and regulations on sludge final disposal have led to the build-up of landfill cells due to the increasing sludge disposal. There is a noteworthy concern of uncontrolled odours leaving the facility boundary during handling and disposal activities when sewage sludge is being received. Sources of the odours may include loaded and emptied hauling vehicles, track out and spillage of sewage sludge on haul roads or public roads near the facility, the management of sewage sludge at the working face, and the increased landfill gas production (Allen, 2012).

Overall, the development of a sludge management system needs to be seen within the framework of “sustainability” concept prioritized for developing countries. Thus, the advancement of correct and practical sludge management systems must be encouraged mainly through integrated approaches addressed towards the reduction of the amount of sludge to be discarded. Among the approaches are the application of reuse option intended to recover useful products or energy instead of simple disposal ones, development of integrated systems that are self-sustaining from the energy point of view, production of materials that can be safely handled from the environmental aspect and conveniently marketed, and development of operational systems appropriate to local context including social ones (Spinosa, 2011).

1.2 Problem Statement

According to Ujang and Salmiati (2011), the rise in the population has led to the increase in sludge volume. Moreover, due to the expanding development in the country, the volume of wastewater generation will increase annually and the volume of the sludge produced from the treatment process will proportionately increase as well. This will bring about an increase in sludge waste disposed of to the landfill sites and also increase in the emissions of greenhouse gases (GHGs) from the landfill sites.

In Malaysia, there is currently a rising awareness in support of tackling climate change. In line with Malaysian government's effort to support United Nations of Environment Programme (UNEP) through the implementation of climate change endeavours into the developmental process, a pilot study had been conducted in Iskandar Malaysia (IM) where the findings were obtained by modelling and facilitating the transition of IM, one of the fastest growing areas in Malaysia, in the effort for creating a low-carbon society for every sector which naturally includes waste management (Gomi *et al.*, 2012). According to the work by Khazanah Nasional (2006) and Ho *et al.* (2013), it is projected that the population living in the city will increase from 1.35 million in 2005 to over 3 million by 2025, and the gross domestic product (GDP) will almost quadruple from Malaysian Ringgit (MYR) 35.7 billion to MYR141.4 billion over the same period. For now, the current annual emissions of IM are 12.6 million tonnes of CO_2. Under the business as usual (BaU) scenario, the GHG emissions will increase to 45.5 million t-CO_2 or 3.6 times higher than in 2005. By implementing the mitigation options available by 2025, the emissions should be able to be reduced by 60% and suppressed to 19.6 million t-CO_2 (Gomi *et al.*, 2009).

The Intergovernmental Panel on Climate Change (IPCC) has developed a number of methods to assist countries in quantifying GHG emissions from various sectors. The most recent method developed is the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC). The guidelines are internationally accepted and designed to allow countries to determine their GHG emissions. In 1994 and 2000, Malaysia applied the IPCC Guidelines to produce the Initial and Second National Communication to the UNFCCC report on the country's own GHG inventory. However, both reports used the former "Revised IPCC 1996 Guidelines" for the GHG calculation. In support of a low-carbon society, the use of the 2006 IPCC Guidelines would allow IM to portray emissions from sludge management by forecasting potential emissions from current and proposed treatment and disposal options that would assist in the decision making process.

1.3 Research Objectives

The objectives of this research was to evaluate energy recovery potential via sludge management from sewage treatment plants (STPs) in Iskandar Malaysia. To achieve this, three objectives were identified:

i. To investigate the technology used for sludge treatment and disposal pertaining to their use in Iskandar Malaysia

ii. To investigate greenhouse gas estimation methods and apply their principle to the water industry, sludge management in particular.

iii. To compare the conceptual model for each option by highlighting the energy inputs and CH_4 emissions for business as usual (BaU) and counter measure (CM) scenarios.

1.4 Scope of Research

i. The type of sludge that is of interest in this research is domestic sludge; industrial sludge is not considered.

ii. The local authorities in Iskandar Malaysia involved were Johor Bahru Tengah Municipal Council (MPJBT), Kulai Municipal Council (MPKu), and Johor

Bahru City Council (MBJB) only, whereas Pasir Gudang Municipal Council (MPPG) and Johor Bahru City Council (MBJB) were excluded.

iii. The data used in this research was secondary data. The secondary data collection was done throughout this research and retrieved from government websites, blueprints, reports, journals, and articles from reliable sources. Retrieved data, if deemed fit and suitable, was then used as a variable in the calculation of potential CH_4 emissions.

1.5 Significance of Research

The significance of this research is to be able to forecast methane (CH_4) emission from sludge management in IM based on different treatment technologies and assumptions. The increase in CH_4 emission was estimated based on (1) 2025 BaU (Business as Usual without mitigation measures) and (2) 2025 CM (with Counter Mitigation measures) assumptions of employed technologies as well as the potential to reduce the emissions by low-carbon measures available by the year 2025. This research is expected to assist the study area in making decisions on which sludge treatment and disposal options are suitable for local implementation in order to achieve a low-carbon scenario in the water treatment industry.

5.2 Recommendations

A number of recommendations are as follows:

- IPCC offers a series of methods, from general to detail. However, due to the use of secondary data, the most general method were used. Highly recommended, that if primary data were to be collected, a more detailed approach can be applied.

- The use of default values for methane potential and emission factor are internationally used, including in this research, which covers broad spectrum. Values that represent Malaysia conditions were not made available, since previous two National Communication (INC and NC2) report, used default values provided by IPCC.

REFERENCES

Abu-Orf, M., Stinson, B., Davies, G., Goss, T., Peric, M., Amad, S., Taylor, R., Belschner, D. and Hartz, F. (2011). Energy Recovery from Anaerobic Digestion When Compared To Close-Coupled Gasification. *16th European Biosolids and Organic Resources Conference.* 14-16 November. Leeds, United Kingdom, 1-19.

Akwo, N.S. (2008). *A Life Cycle Assessment of Sewage Sludge Treatment Options.* Aalborg University.

Allen, P.S. (2012). *Sewage Sludge Disposal at Solid Waste Landfills*. Ohio Environmental Protection Agency.

Ashrafi, O. (2012). *Estimation of Greenhouse Gas Emissions in Wastewater Treatment Plant of Pulp & Paper Industry.* Quebec, Canada.

Attah, N.V. (2010). *Environmental Sustainability and Sustainable Growth: A Global Outlook.*University of Pennsylvania.

Baki, A., Abdul-Talib, S., Hamid, M. H. A., Chin, K. B., & Salleh, M. T (2006). The prospect of energy from sewage sludge in Malaysia. *Energy for Sustainable Development*, March, 1-3.

Barton, H. (2000). *Conflicting perceptions of neighbourhood: In Sustainable Communities*. Barton H (ed.), London: Earthscan

Beecher, N. (2008). *A Greenhouse Gas Emission Analyst of Bisolid Management Options for Merrimack, NH.* Tamwirth, NH.

Bouteiller, C.D. (2010). *Evaluating the carbon footprint of alternative sludge treatment and disposal methods.* Imperial College London, United Kingdom.

Butler Manufacturing Services (2013). Sewage Parameters 3: Population Equivalent. http://www.butlerms.com/index.php/blog/education-blog/159-sewage parameters-3-population-equivalent-pe-part-1solids-ss

Chua SC, Oh TH (2010). *Review on Malaysia's national energy developments: key policies, agencies, programmes and international involvements*. Renewable and Sustainable Energy Reviews. 14(9):2916–25.

Deublein, D., & Steinhauser (2010). *A. Biogas from waste and renewable resources*. Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

D. Fytili, A. Zabaniotou. (2008). Utilization of sewage sludge in EU application of old and new methods—A review. *Renewable and Sustainable Energy Reviews.* 12 (2008), 116-140.

Du Plessis, C. (2000). Cities and sustainability: sustaining our cultural heritage. *In Cities and Sustainability: Sustaining Our Cultural Heritage.*

Brandon P, Lombardi P, Perera S (eds.). Sri Lanka: Kandalama Environmental Leader. (2014, December 17). ACT Wastewater Treatment Cuts Operating Costs, Recycles Waste [News].

Retrieved from http://www.environmentalleader.com/2014/12/17/act-wastewater-treatment-cuts-operating-costs-recycles-waste/

Elder & Lallanila (2015). What is the Greenhouse Gas Effect? (literally) [Blog Post]. Retrieved from http://www.livescience.com/37743-greenhouse-effect.html

Environment Protection Agency, EPA (2014). Municipal Solid Waste Generation, Recycling, and Disposal in the United States : Facts and Figures for 2012

Giddings, B., Hopwwod, B., and O'Brien, G. (2002). Environment, Economy and Society: Fitting Them Together Into Sustainable Development. *Sustainable Development.* 10, 187-196.

Gould, M., Tsang, R. and Bandi, R.T. (2008). A Greenhouse Gas Emissions Accounting Model for Biosolids Management Planning. *2008 NC AWWA-WEF Annual Conference*. 1-16

Gomi, K. (2008). [Power Point]. Development of Extended Snap Shot Tool and Application to Local LCS. NIES. Kyoto University, Tsukuba, Japan.

Gomi, K. (2009). *Low-Carbon City 2025 Low-Carbon City 2025.* Vice Chancellor Council & Japan Society For The Promotion Of Science The Planning Of Urban Energy And Environmental Systems (Group Vii)

Gomi, Kei. (2010). [Power Point]. *Extended Snapshot Tool. Bangkok, Thailand.* Kyoto University, Japan.

Gomi, K., Hasegawa, T., Siong, H.C., and Matsuoka, Y. (2012). *Developing tools for* *low-carbon society scenarios in a developing country: a case study in Malaysia.* Kyoto University, Japan.

Hall, J (2003). *Session 3 Technology and innovative options related to sludge management.* (165). United Kingdom. Wrc

Hamid, H., and Baki, A.M. (2005). Sewage Treatment Trends in Malaysia: Series 3 .Indah Water Konsortium. *The Ingenieur.* 46-53.

Hammond, G., and Jones, C. (2008). *INVENTORY OF CARBON & ENERGY (ICE) Version 1.6a.* University of Bath, United Kingdom.

Hicks, A.L. (2010). *Modelling Greenhouse Gas Emissions from Conventional Wastewater Treatment Plants in South Carolina.* Clemson University.

Ho, C S, Matsuoka, Y, Chau, L W, Teh, B T, Simson, J J, & Gomi, K. (2013). Blueprint for the development of low carbon society scenarios for Asian regions- case study of Iskandar Malaysia. IOP Conference Series: Earth and Environmental Science, 16(1), 012125.

Ibrahim, Ismail. (2013). [Power Point]. *Low Carbon Society- the Asian drive forward.* Iskandar Regional Development Authority, IRDA.

Ibrahim, N and Thong, T.B. (2011). Low Carbon Lifestyle: A Key in Moving Iskandar Malaysia towards Low Carbon Region. The International Symposium on Society and Resource Management. 14-17 June. Kota Kinabalu, Malaysia. 1-7.

IPCC (2014). *IPCC, Intergovernmental Panel on Climate Change, Organization*. Retrieved from http://www.ipcc.ch/organization/organization.shtml

IPCC (2014). *IPCC, Intergovernmental Panel on Climate Change. Structure*. Retrieved from http://www.ipcc.ch/organization/organization_structure.shtml

IPCC (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IRDA (2011). *Renewable Energy & Energy Efficiency: Blueprint for Iskandar Malaysia.* 1-23.

International Union for Conservation of Nature [IUCN]. (2012). The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century. Retrieved from: http://cmsdata.iucn.org/downloads/iucn_future_of_sustanabil ity.pdf

IWK (2007). Corporate Sustainability Report 2007. 13 years of Environmental Accomplishment (1994-2007).

IWK (2009). Sustainability Report 2008-2009: Towards Green Agenda.

IWK (2010). Sustainability Report 2010: Achieving Excellence through Innovation.

IWK (2011). Sustainability Report 2011. Making a Difference to Our Lives and Environment. Via a Greener Today for Cleaner & Safe Tomorrow.

Jaafar, M.Z., Kheng, W.H., and Kamaruddin, N. (2003). Greener energy solutions for sustainable future: issues and challenges for Malaysia. *Energy Policy*. 31, 1061-1072.

Jakobsson, C. and Palm, O. (2012). *Sewage Sludge Management in Relation to EU requirements. Case Study Latvia. Recycling of Nutrients.* Sweden.

JICA (2009). *LOW-CARBON CITY 2025: SUSTAINABLE ISKANDAR MALAYSIA.* 1, 1-32.

JICA (2010). *Development of Low carbon Society Scenarios for Iskandar Malaysia. AIM Workshop.* Bangkok, Thailand.

Joeman, B.D. (2011). Low Carbon Cities and Climate Change Adaptation: The Iskandar Experience. *MNRE National Symposium on Climate Change Adaptation.* 18 November.

Joeman, B.D. (2012). [Power Point]. *Sustainable Low Carbon Scenario Development: LCS for Iskandar Malaysia.* 3rd High Level Seminar on Environmentally Sustainable Cities. Iskandar Regional Development Authority.

Joeman, B.D. (2013). [Power Point]. *Iskandar Malaysia: Smart City Yokohom-Introducing Low Carbon Cities in Asia; Practice & Challenges for Sustainable Urban Development.* Iskandar Regional Development Authority (IRDA).

Johnston, A.H. & Karanfil, T. (2012). *Developing a Greenhouse Gas Emissions Calculation Tool for Water Utilities.* Clemson University.

Jorge, F.C. and Dinis, M.A.P. (2012). Sewage sludge disposal with energy recovery: a review. *Proceedings of the Institution of Civil Engineers Waste and Resource Management 166.* 15 October. Porto, Portugal. 166 (WR1), 14-28.

Karius, R. (2011). *Developing an integrated concept for sewage sludge treatment and disposal from municipal wastewater treatment systems in (peri-) urban areas in Vietnam.* Dresden.

Keirungi, J. (2006). *The Design and Assessment of an Integrated Municipal Waste*

Beneficiation Facility: Towards Improved Sewage Sludge Management in Developing Countries. Rhodes University.

Khazanah Nasional 2006 Comprehensive Development Plan for South Johor Economic Region 2006-2025 Kuala Lumpur: Khazanah Nasional

Kubeczko, K. (2004). *Monitoring Climate Policy - A Full Carbon Accounting Approach based on Material Flow Analysis*. Austria.

Leong, Y.P., Mustapa, S.I., and Hashim, A.H. (2011). Climate Change Challenges on CO_2 Emission Reduction for Developing Countries: A Case for Malaysia's Agenda for Action. *The International Journal of Climate Change: Impacts and Responses.* 2, 1-20.

Lee, D.J., and Tay, J.H. (2004). Energy Recovery in Sludge Management Processes. *Journal of Residuals Science & Technology.* 1(2), 133-137.

Lim, J.H. (2012). *Assessment of Sludge Management Options in a Waste Water Treatment Plant.* Waterloo, Canada.

MacElroy, P (2014). Black & Veatch Building a world of Difference. [News]. Retrieved from http://bv.com/Home/news/solutions/energy/deriving-energy-from-waste

Maunsell Malaysia (2009). *Integrated Solid Waste Management Blueprint for Iskandar Malaysia Stage 3 – Integrated Solid Waste Management Blueprint.* Document No.: KL09020.001.

MPC (2010). *Sustainable Development Initiatives in Malaysia.* Malaysia Productivity Corporation. MPC.

Muller, C. (2007). *Anaerobic Digestion of Biodegradable Solid Waste in Low – and Middle – Income Countries. Overview over existing technologies and relevant case studies.* Dubendorf, Schwetz. Eawag aquatic research.

Murray. A., Horvath, A. and Nelson, K.L. (2007). Hybrid Life-Cycle Environmental and Cost Inventory of Sewage Sludge Treatment and End-Use Scenarios: A Case Study from China.

Mustapa SI, Leong YP, Hashim AH (2010). Issues and challenges of renewable energy development: a Malaysian experience. *Energy and sustainable development: issues and strategies*.

Neyens et., al. (2010). Current Sludge Disposal and Alternatives and Cost in Critical Areas. In: Foladori et al. *Sludge Reduction Technologies in Wastewater Treatments Plants.* London. IWA Publishing. 2010

Palandri, M. (2012). *Fugitive Greenhouse Gas Emissions from Wastewater Treatment: Understanding Emission Generation Processes and Development of Appropriate Sampling Methods.* The University of Western Australia, Australia.

PATEC (2011).

Peltoniemi, M. (2007). *Country-scale carbon accounting of the vegetation and mineral soils of Finland.* University of Helsinki.

Petavratzi, Evaggelia., and Wilson, S. (2007). *Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material. Case Study: Incinerated sewage sludge ash in facing bricks.* United Kingdom.

Pradel, M., Reverdy, A.L. and Irstea. (2013). Assessing GHG emissions from sludge treatment and disposal routes – the method behind GESTABoues tool. *ORBIT2012, Global Emission for Organic Resources and Waste Management.* 1-28 January. France. 1, 1-9.

Robbins, D., Strande, L., and Doczi, J. (2012). Opportunities in Fecal Sludge Management for Cities in Developing Countries: Experiences from the Philippines. Pp 1-10.

Rothausen, S.G.S.A and Conway, D. (2011). Greenhouse-gas emissions from energy use in the water sector. *Nature Climate Change.* 1, 210-219.

Roy, M.M., Dutta, A., Corscadden, K., Havard, P., Dickie, L. (2011). Review of biosolids management options and co-incineration of a biosolid-derived fuel. *Waste Management. 31* (2011), 2228-2235. Elsevier.

RTI International (2010). *Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal Wastewater Treatment Ethanol Fermentation.* Research Triangle Park, NC.

Salmiati and Ujang, Z (2011).

Seaman Corporation. (2010). *Anaerobic Digestion: Save Cost and Lower Carbon Footprint* [Brochure]. Wooster, Ohio. Seamancorp.

Second National Communication to the UNFCCC. Ministry of Natural Resources and Environment Malaysia; 2010.

Sieger, R.B. and O’Malley, D. (2002). *Energy Recovery from Wastewater Treatment Plant Sludge.* Brown and Caldwell.

Silva. J.P. (2007). *Sustainable Water Management in the City of the Future.* European

Union.

Simson, J.J. (2012). *Study on Sustainable Low Carbon Society in Malaysian Regional Development.* Kyoto University, Japan.

Siong, H.C. (2013). Iskandar Malaysia: Development of Low Carbon Society Scenarios for Asian Regions. *Eco-CSR Japan. Japan International Cooperation in Eco-CSR,* Retrieved May 19, 2014. From http://www.env.go.jp/earth/coop/eco-csrjapan/en/dr-ho.html

Smith, S.R. (2011). *Management, Use, and Disposal of Sewage Sludge.* Smith, S.R. *Waste Management and Minimization*. (1-10). United Kingdom. EOLSS.

Snip, L. (2009). *Quantifying the greenhouse gas emissions of wastewater treatment plants.* Wageningen University.

Spamer, E. (2009). *An investigation into sustainable solid waste management alternatives for the Drakenstein Municipal Area.* University of Stellenbosch.

Spinosa, L (2011).

Stillwell A.S., Hoppock, D.C., and Webber, M.E. (2010). *Energy Recovery from Wastewater Treatment Plants in the United States: A Case Study of the Energy-Water Nexus. Sustainability* (pp 945-962). Texas, U.S.A.

Sutton, P. (2004). A Perspective on environmental sustainability? *Strategy of Green Innovations.* 2, 1-32.

Suwanteep, K., Chavalparit, O. and Ongwandee, M. (2011). *Evaluation of Carbon footprint of activated sludge wastewater treatment system.*

Sylvis (2009*). The Biosolids Emissions Assessment Model (BEAM): A Method for Determining Greenhouse Gas Emissions from Canadian Biosolids Management Practices.* British Columbia, Canada.

Tang, J. (2004). *A Case Study of a Hotel Solid Waste Management Program in Bali, Indonesia.* Ontario, Canada.

Tyagi, V.K. and LienLo, S. (2013). Sludge: A waste or renewable source for energy and Resources Recovery? *Renewable and Sustainable Energy Reviews.* 25, 708–728. Elsevier.

van Nes, W.J. (2006). Asia Hits the Gas. Biogas from Anaerobic digestion rolls out across Asia. *Renewable Energy World.* January-February. Pp 102-111.

Veerannan, V.J.N. (2011). *An investigation on the energy recovery potential of sewage sludge in Malaysia through biogas generation*. Universiti Teknologi PETRONAS, Perak.

Wan Abdul Rahim, W.A. (2011). [Power Point] An Overview of Malaysia's Sewerage Management.

Warner, E.S. (2009). *Evaluating Life Cycle Assessment (LCA) Models For Use In A Low Carbon Fuel Standard Policy.* University of Minesota.

Wachter, David (2005). Sustainability assessment in Switzerland: From theory to practice, EASY-ECO 2005-2007, 1st Conference, Manchester (UK), 15-17 June.

Wu, W.(2011). *Carbon Footprint A Case Study on the Municipality of Haninge.* Stockholm.

Xu, C. and Lancaster, J. (2012). *Review: Treatment of Secondary Sludge for Energy Recovery*. (187-212).

Zhang, C. (2012). *Assessing Greenhouse Gas Emission from Waste Management in Eu Countries.* University of Jyväskylä.