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Towards a Cleaner Environment: A study on the Potential Utilization of Solid Waste as Fertilizer and Energy Sources in Malaysia

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Abstract— **As the world seeks a cleaner environment there is constant need to continually seek new ways and methods to achieving sustainable practices. Solid waste generation is one of the major challenges for Malaysia to address in the light of her Vision 2020 as preventing and managing waste is in the hub of sustainable development. Malaysia, like most other developing countries, is facing uncontrolled increase in solid waste generation due to economic growth and industrialization but the waste disposal practices poses a serious threat to achieving vision 2020. The average amount of municipal solid waste (MSW) generated in Malaysia is about 0.5–1.7 kg/person/day, where about 17,000 tonnes of municipal solid wastes are generated in Peninsular Malaysia daily which is estimated to increase to more than 30,000 tonnes per day in the year 2020. Literature shows that Malaysia's major waste management approaches is landfill. About 95% of the wastes collected are sent to landfill with little recycling activities. Composting is not a common practice in Malaysia's waste management where the main component of the Malaysian MSW is food materials which contribute about 45% of the total waste generated by weight. Based on the waste composition, composting enhancement is proposed as an addition to other approaches. Similarly, the second main component of municipal solid waste in Malaysia is plastic - 24% and waste papers 7% which holds a great potential for incineration. Sustainable waste management is the ability to utilize resources more efficiently; thus the conversion of most solid waste to fertilizer or fuel for energy plants can help protect and sustain the environment for clean and better living. This paper looks into the potential of utilizing solid waste as resource for fertilizer or energy production in Malaysia. The study also discusses mechanical/biological treatment of waste as a separation process of municipal solid waste into components, thus channeling the different component to a more sustainable treatment approach thereby reducing the amount of waste that is sent to landfill.**

Keywords - Municipal solid waste; Mechanical/Biological treatment, Composting, Landfill, Energy sources and potentials

I. INTRODUCTION

Malaysia is one of the fast developing countries in the world. Industrialization, population growth, tourism and great influx of foreign workforce/students lead to massive development projects to build the latest designs of residential and business buildings, to construct spacious highways, tourist resorts etc. This development projects are needed to enhance the quality of the lives of citizens in the country but ecologically, these development projects affect the environment directly or indirectly. The paper looks on environmental protection (Solid Waste Management) as relating to the economic growth and development in Malaysia and some sustainable ways of managing and using solid wastes for other purposes like refuse derived fuels to create a more healthier environment. One of the major contributors to the degradation of environmental quality is the solid waste from household and industries. Municipal solid waste emits nitric oxide and methane gas that contribute about 20% to the greenhouse effect [1], thus there is need to manage these household wastes in a proper way to minimize the emission of these dangerous gas (methane) which is 21 times more potent than carbon dioxide [2].

A. *Malaysia's Waste Generation and Composition*

In Malaysia, the average amount of municipal solid waste generated was approximately about 0.5–1.7 kg/person/day [3]. The sources and quantities of municipal solid waste vary among local authorities in Malaysia depending on the township size and level of economic standards. According to [4], waste generation may range from 45 tonnes/day of municipal solid waste (MSW) in Kluang, which is a small town in a southern part of Peninsular Malaysia, to 3000 tonnes/day in Kuala Lumpur. The average amount of municipal solid waste (MSW) generated in Peninsular Malaysia daily is about 17,000 tonnes which is estimated to increase to more than 30,000 tonnes per day in the year 2020 [5]. MSW generated in Malaysia consists of different constituents biodegradable materials (food waste, Garden waste, Animal waste and Material contaminated by such waste), resistant polymers, paper, Wood, Textiles, Leather, Plastic, Rubber, Paint, oil, grease, chemical, organic sludge, glass, ceramic, mineral soil, concrete, and masonry (construction debris). The 9th Malaysia Plan estimated about 45% of the waste is made up of food waste, 24% of plastic, 7% paper materials, 6% of iron and glass while others made of the remaining percentage [5, 6].

B. The Current MSW Management Techniques in Malaysia

Malaysia's current major waste management approaches are landfill and recycling. About 95% of the municipal solid wastes collected are sent to landfill with little recycling activities [5]. The landfill is not purely sanitary and produces some greenhouse gasses like nitric oxide and methane; leachate are also products of landfill which run off from landfill sites in high raining season, similarly leakage through the walls of the landfill site leads to pollution of the underground water. In Malaysia, there are about 291 landfill sites all over the country as at April 2007 where 112 of these sites are not in operation and just 179 still operating with only 10 of these sites meeting the sanitary condition [5]. Separation/treatment of waste (mechanical biological treatment of waste) has not been well practiced [7]; it is one of the waste management process that need to discussed and educate the people, thus put in practice for cleaner environment. It was also noted by [8] that landfill waste management practice creates nuisance owing to the generation of highly concentrated leachate, methane gas emission, and quick settlement of waste due to decomposition that eventually affects the stability of landfill dump/site. Waste management and disposal solution should follow proper sorting, pre-treatment (mechanical biological treatment system) and in the worst case send to landfill.

C. Mechanical Biological Treatment of Solid Waste

The most economical and widely practiced alternative for the elimination of MSW is sanitary landfill. However, leachate and biogas are produced due to uncontrolled degradation of bio-fraction contained in the waste. Generally, MSW stream in most parts of Malaysia is highly biodegradable; thus direct landfill practice of the MSW without prior treatment is not environmentally-friendly approach [8]. The pre-treatment method can be achieved using the mechanical biological treatment techniques.

Mechanical biological treatment of waste is a generic process for the integration of several processes commonly found in other waste management technologies such as Materials Recovery Facilities (MRFs), sorting (figures 1), composting or anaerobic digestion and energy recovery [9,10,11,12]. MBT therefore compliments, but does not replace, other waste management technologies such as recycling and composting as part of the integrated waste management system. In this view, the MSW can be handled and managed in a more environmentally approach using mechanical biological treatment as it unites many approach in one technique, thus conserves the environment and potential natural resources. Some key advantages of MBT are as follows [10,11]:

- ♦ It can be configured to achieve several different aims.
- ♦ Pre-treatment of waste going to landfill;
- ♦ Diversion of non-biodegradable and biodegradable MSW going to landfill through the mechanical sorting of MSW into materials for recycling and/or energy recovery as refuse derived fuel (RDF);
- ♦ Diversion of biodegradable MSW going to landfill by -reducing the dry mass of Biodegradable Municipal Waste (BMW) prior to landfill and reducing the biodegradability of BMW prior to landfill.
- ♦ Stabilisation into a compost-like output (CLO) for use on agricultural lands;
- ♦ Conversion into a combustible biogas for energy recovery; and/or
- ♦ Drying materials to produce a high calorific organic rich fraction for use as RDF.

Figure 1. Mechanical Sorting of MSW

The technique for Mechanical Biological Treatment of MSW is analyzed in the figure 2.

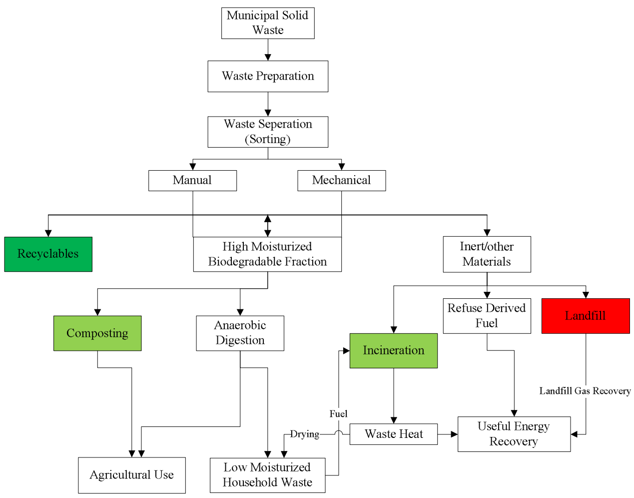

Figure 2. Mechanical Biological Treatment Techniques

i.) *Waste preparation:* Initial waste preparation may take the form of simple removal of contrary objects, such as mattresses, carpets or other bulky wastes, which could cause obstruction to processing equipment downstream. Other techniques are to split open refuse bags, thereby liberating the content or to shred and homogenise the waste into smaller particle sizes suitable for a variety of separation processes, or subsequent biological treatment depending on the MBT process employed.

ii.) *Waste separation:* The stage of sorting mixed waste into different fractions using mechanical means. No sorting is required if the objective of the MBT process is to pre-treat all the residual MSW to produce a stabilised output for disposal to landfill. Sorting the waste allows an MBT process to separate different materials which are suitable for different end uses. Potential end uses include material recycling, biological treatment, energy recovery through the production of RDF, and landfill [11]. A variety of different techniques can be employed as shown in table 1. Separation technologies exploit varying properties of the different materials in the waste. These properties include the size and shape of different objects, their density, weight, magnetism property and electrical conductivity.

TABLE I. MBT - WASTE SEPARATION TECHNIQUES [10,11]

Separation Technique	Waste Separation Techniques		
	Separation Property	***Materials targeted***	***Key Concerns***
Trommels and Screens	Size	Oversize paper, plastic, glass,	Air containment and cleaning
Manual Separation	Visual examination	Plastics, contaminants	Health/Safety , Role Ethics
Magnetic Separation	Magnetic Properties	Ferrous metals	Proven technique
Eddy Current Separation	Electrical Conductivit y	Non ferrous metals	Proven technique
Wet Sorting Technology	Differential Densities	Floats Plastics, stones, glass	Produces wet waste streams
Air Classification	Weight	Light plastics, paper, Heavy stones, glass	Air cleaning
Ballistic Separation	Density and Elasticity	Light plastics, paper, Heavy stones, glass	Rates of throughput
Optical Separation	Diffraction	Specific plastic polymers	Rates of throughput

iii.) *Biological treatment:* The biological element of an MBT process is the treatment of the high moisturized biodegradable fraction of MSW in the following biological processes: aerobic Bio-drying, aerobic In-vessel composting and anaerobic digestion.

The biodegradable portion of the MSW can be converted to useful plant/agricultural resource. The average moisture content is relatively high, that is greater than or equal to 50%. In this regard, the waste is not suitable for incineration because it requires high energy input to bring the waste to its ignition level. Simple aerobic composting and anaerobic digestion are the biological treatment options to overcome the high organic fraction and moisture content of waste. MBT processing of mechanically separated organics can produce partially/fully stabilized and sanitised compost-like-outputs (CLO) or partially stabilized digestate material. Digestate material is produced from an MBT process that uses anaerobic digestion as the biological process. CLO is usually the term used for an output using an aerobic process such as bio-drying or in-vessel composting. The potential applications of these outputs are dependent upon their quality and legislative and market conditions. CLO and digestate has the potential to be used as a source of organic matter to improve certain low quality soils, e.g. in the restoration of brown field sites, or for landfill cap restoration [11].

II. WASTE TO SOIL ADDITIVES (COMPOSTING)

The landfill waste treatment effect cannot be over emphasised as municipal solid wastes (MSW) sent to landfill leads to several environmental problems such as the formation of leachate contaminating under groundwater and the emission of greenhouse gases. Composting is nature's way of recycling biodegrades organic waste (food waste, leaves, grass trimmings, paper, wood, feathers, crop residue etc.), and turns it into a valuable organic soil additives. According to [13], Asia is expected to experience the largest increase in the production of biodegradable MSW ranging from 220 million tons to 418 million tons from 1995 to 2025. From 1995 to 2025, food waste disposed in landfills will potentiality increase world CH_4 emissions from 27 million tons to 48 million tons and the landfill share of global anthropogenic emissions from 8% to 10% [13]. From the analysis of [5], the biodegradable/food waste contributes about 45% of the waste generated in Peninsular Malaysia. Converting this large portion of MSW to soil additives will help achieve clean environment and save cost of MSW management. If cities in Malaysia employ and treat their food waste by proper sorting and composting or anaerobic digestion individually or by government setting composting site at different locality where these wastes can be composted, more CH_4 emissions can be curtailed while improving crop yields. It would also reduce MSW transportation load by great percentage. Based on the agricultural potentials of Malaysia, MSW would require less transportation and landfilling if proper sorting is introduced and made a law such that all the biodegradable/food waste can be collected in a separate bin where they can be collected by local authorities and send to proper composting site if the individual don't want to compost by themselves. This will reduce the cost of waste collection, transportation and save the land required for landfilling, as well as reduce the environmental ramifications.

III. WASTE TO ENERGY

According to [5], over 30% (24% of plastic and 7% paper) of MSW generated in Peninsular Malaysia are refuse derived fuel and can be utilised for heat generation when it cannot be recycled and other waste like food materials when dried can also be used as source of fuel. This portion of this paper focuses on the use of the refuse derived fuel from MBT as energy resources. Refuse derived fuel can be used in hot water generation for domestic and industrial purposes but in a case where the fuel does not conforms with the legislative rules of a state, such fuels are treated as waste in incinerators. Incineration is a waste treatment process that involves the combustion of waste materials which can be described as "thermal treatment". It converts the waste into ash, flue gas, and heat, where the temperature of the flue gas ranges from

650°C - 1000°C [14, 15]. Most of the heat generated from incineration is wasted to the atmosphere as waste heat.

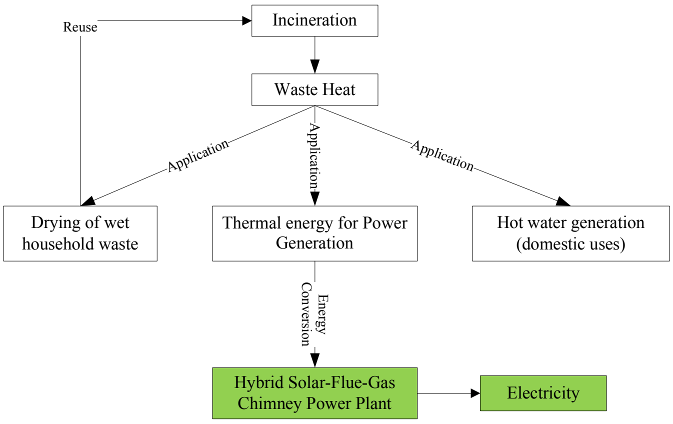

Figure 3. Energy Recovery from Incineration

A. *Use of Incineration Waste Heat for Power Generation*

The use of waste heat for power generation can be applied in the generation of steam for steam turbine power plants and also can be used for artificial wind generation for wind turbine energy converter. The later is where incineration waste heat will find great application and also reduce the exit temperature of the flue before getting to the atmosphere [15]. Artificial wind power generator otherwise known as solar chimney power plant is a solar thermal power plant that utilizes the greenhouse concept and chimney suction and buoyancy effect to generate moving air (air in motion). The kinetic energy in the moving air is extracted by stage wind turbines at the base of the chimney to generate electricity. The above named power plant has been tested since 1981 and proved a success but has low efficiency, therefore need some improvement and can be achieved by enhancing the heat transfer in the collector and the chimney. The desire of ensuring continuous power output or enhancing the efficiency of the solar chimney system has remained a challenge to researchers till date thus this new approach [14, 15]. An alternate enhancement technique has been introduced which utilizes waste heat from flue gas produced from power plants, furnaces and other industrial operations to supplement the solar energy input at the collector to achieve uninterruptible power generation and increase the power output of the solar chimney power plan [15,16].

B. *The Concept of the Hybrid Solar Flue Gas Chimney Powe Plant*

The hybrid solar flue gas chimney power plant employ same concept of the traditional solar chimney power plant. The sun penetrates through the transparent glass and heat the ground (open solar-air collector) as shown in figure 4, the air raise due to density deference between the ambient air and the air trapped in the greenhouse/open-solar-air collector. At the centre of the canopy of the collector, is a thermal engine otherwise called solar chimney which creates suctions and buoyancy to increase the air velocity and dray in more air from ambient. The warm moving air which is energized kinetically rotates staged turbine(s) at the base of the chimney to generate electricity (figure 4).

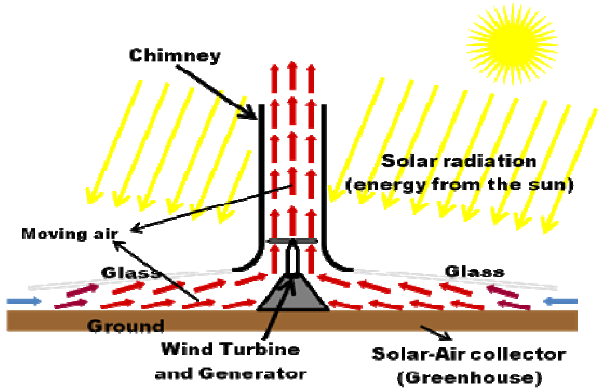

Figure 4: Schematic view of Solar Chimney Power Plant

On the hybrid solar-flue-gas chimney power plant (figures 5-7), the system is designed to include a flue gas channel where incineration waste heat can be recovered to useful energy. It is made up of transparent cover which is made of glass. The flue gas channel is the external heat source supply while the transparent cover is the solar admittance surface. Between the flue gas channel and the greenhouse (air flow channel) is an absorber plate that absorb heat from both the flue gas and the sun. The system is designed for high efficiency the absorber plate is inclined at an optimum angle the absorb the maximum available solar radiation in the area and the second absorber plate is inclined at 45° to enhance buoyancy before getting to the chimney base thereby increase the air velocity.

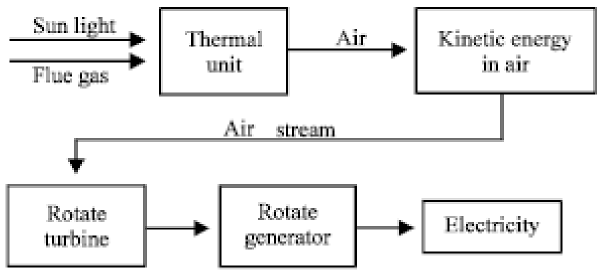

Figure 5. Energy Conversion Process Block Diagram

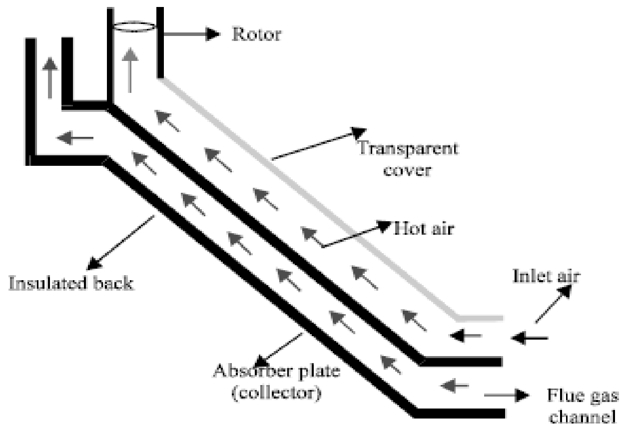

Figure 6. Schematic side view of a solar flue gas chimney experimental model

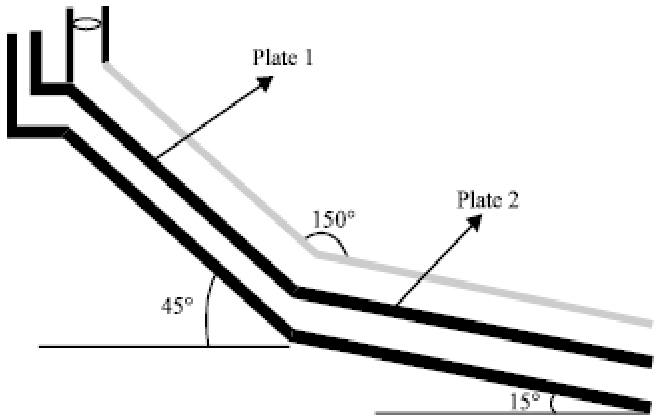

Figure 7: Design angles of the proposed thermal unit

On the experimental process in the plant, it was found that the efficiency of the plant can be enhance to about 20% higher using a supplementary heat (flue-gas waste heat) and the night power generation taken care of, thus solving the night mode power generation challenge associated with solar energy power systems.

IV. Conclusion

Malaysia produces thousands of tonnes of waste per day which about 95% is usually disposed of in landfills. Landfill as waste management techniques emits nitric oxides and other greenhouse gases like methane gas (CH_4) which contributes to the green house effect and climate change. Mechanical Biological Treatment of waste has not been in practice in Malaysia and need to be considered as a pre-treatment technique as it will enhance the waste management process and create room for energy recovery from some high calorific waste materials which are lost to landfill and as much will also increase the amount of recyclable materials. In this work, the use of MBT shows that some of the biodegradable materials when employed and converted to soil additives by composting will be very useful for agricultural purposes. Introduction of individual sorting of waste at different homes will help the authority to select the wastes that are good for composting and also reduce the cost of transportation when composting sites are situated at different locality. This will in turn create jobs and promote greener soil additive and gardening even in the cities. With MBT, some of the biodegradable wastes that escape sorting in the different homes can be sorted and recover them for composting while the high calorific waste materials can be used as waste derived fuels or if it did not conform with the health standard of the government, they can be sent to incineration and the waste heat utilized for other energy purposes. The use of incineration will reduce the waste management challenges in Malaysia and the heat generated from the incineration can be recovered for useful proposes as in power generation and hot water generation for industrial and household uses. The solar chimney power plant can be hybrid with the incineration waste heat to generate electricity for the locality and reduce the heat from the incinerator before leaving to the atmosphere. Similarly the cost of energy form the hybrid solar-flue-gas chimney power plant can drastically reduce and compete with conventional electrical energy price while the energy generated is almost free from the fuel source (solar and waste heat).

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References

[1] Md. Abdul Jalil , "Sustainable Development in Malaysia: A Case Study on Household Waste Management" Journal of Sustainable Development, 2010, pp. 91-102

[2] Bavani, M. and Phon, L.L. "Using worms to reduce organic waste: DBKL to embark on a pilot project soon." *The Star online*, November 23, 2009.

[3] Sivapalan K., Muhd Noor M. Y., Kamaruzzaman Sopian and Abdul Halim S., "Energy Potential from Municipal Solid Waste in Malaysia" Renewable Energy 2004, 29 (4), pp. 559-567

[4] Rawshan Ara Beguma, Chamhuri Siwar, Joy Jacqueline Pereira and Abdul Hamid Jaafar, "Attitude and behavioral factors in waste management in the construction industry of Malaysia" Resources, Conservation and Recycling 2009, 53 (6), pp. 321-328

[5] Nadzri Yahaya, "Overview Of Solid Waste Management In Malaysia" Workshop on Carbon finance and Municipal Solid Waste Management in Malaysia – EiMAS, 2008

[6] Mohamed Osman Saeed, Mohd Nasir Hassan, M. Abdul Mujeebu, "Development Of Municipal Solid Waste Generation And Recyclable Components Rate Of Kuala Lumpur: Perspective Study" 2008

[7] Elmira Shamshiry, Behzad Nadi, Mazlin Bin Mokhtar, Ibrahim Komoo, Halimaton Saadiah Hashim and Nadzri Yahaya, "Integrated Models for Solid Waste Management in Tourism Regions: Langkawi Island, Malaysia" Journal of Environmental and Public Health , 2011

[8] Solid Waste Management: Issues and Challenges in Asia - Report of the APO Survey on Solid-Waste Management 2004–05, Edited by the Environmental Management Centre, Mumbai, India Published by the Asian Productivity Organization ISBN: 92-833-7058-9. 2007

[9] Chettiyappan Visvanathan, Joseph Tränkler, and Chart Chiemchaisri "Mechanical Biological Pre-Treatment Of Solid Waste Prior To Landfill" http://www.swlf.ait.ac.th/UpdData/National/MWLD.pdf

[10] http://www.arnoldwoolley.com/assets/environmental/MechanicalBiologicalTreatment.pdf "Mechanical Biological Treatment & Mechanical Heat Treatment of Municipal Solid Waste" Crown copyright, 2005.

[11] http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/mbt.pdf "Mechanical Biological Treatment of Municipal Solid Waste" Crown copyright, 2007

[12] http://www.sitaenvtrust.org.uk/research/overview Mechanical Biological Treatment: A Guide for Decision Makers, Processes, Policies and Markets (2005), by Juniper consultancy Ltd for Sita Environmental Trust.

[13] Bijaya K. Adhikari "Urban Food Waste Composting" A master of Science degree Thesis - Department of Bioresource Engineering McGill University, Montreal, 2005

[14] Thermal Energy Equipment: "Waste Heat Recovery - Energy Efficiency Guide for Industry in Asia" – www.energyefficiencyasia.org

[15] Aja Ogboo Chikere, Hussain H. Al-Kayiem and Zainal Ambri Abdul Karim, "Review on the Enhancement Techniques and Introduction of an Alternate Enhancement Technique of Solar Chimney Power Plant". Journal of Applied Science 2011. Pp. 1877-1884.

[16] Al-Kayiem, H.H., M.G. How and L.L. Seow, 2009. Experimental investigation on Solar-Flue gas chimney. J. Energy Power Eng., 3: 25 - 31.