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Implementation of industrial waste heat to power in Southeast Asia: an outlook from the perspective of market potentials, opportunities and success catalysts

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ABSTRACT

As an important way to increase industrial energy efficiency, Waste Heat to Power (WHP) technologies have been gaining popularity in recent years. In order to appraise the market potential of WHP technologies in Southeast Asia, a techno-economic assessment for WHP technologies is conducted in this paper. The technical and economic market potential of WHP in Southeast Asia is estimated to be 1788 MW and 1188 MW respectively. The main market drivers and barriers for WHP market expansion in Southeast Asia are also analyzed. Given the fact that WHP is a far cheaper power generation technology as compared with traditional and renewable power generation, the WHP market is expected to increase fast in the coming years. Mounting electricity price from grid, government emissions regulations and subsidies, the integration of WHP products with original equipment manufacturer, capital cost reduction induced by technology development are identified as the key drivers for the market growth. The above arguments are proofed through the analysis of a power plant WHP project in Southeast Asia.

1. Introduction

Increasing energy demand and stringent energy policies have pushed towards more energy efficient technologies worldwide, Southeast Asia is no exception upon this. In Southeast Asian countries (including Myanmar, Thailand, Cambodia, Singapore, Indonesia, Malaysia, Brunei, Philippines, Vietnam, and Laos), the current developing economic trend is accompanied by an increasing energy demand as well. It is reported that Southeast Asia Gross Domestic Product (GDP) will grow, between 2013 and 2040, on average, 4.6% each year (IEA, 2015), meanwhile the energy demand will increase, on average, 0.64% for every percentage point of GDP growth (Birol, 2008); as a result, it is predicted that the energy demand will continue to ascend in the following decades (Hsiao and Hsiao, 2006). In contrast, there is diminishing energy reserves in most Southeast Asian countries, resulting in an emphasis on energy security and efficiency (Sovacool, 2009). In order to combat these issues, more efficient use of energy has been taken into consideration by all Southeast Asian governments. Fig. 1 shows the trends in energy intensity and GDP per capita for some Southeast Asian country from 1980 to 2011. Most of the countries have reduced their energy intensity although the improvement in energy intensity occurs at a slow pace due to failure in maximizing the available technical potential for energy efficiency (ASEAN, 2015).

The industrial sector, the highest energy consuming sector in Southeast Asia, has been actively engaged in the effort to reduce energy intensity by improving energy efficiency as well. One method to improve energy efficiency is through Waste Heat Recovery (WHR). Waste heat refers to the energy that is generated without being put to practical use and WHR is the process of capturing heat discarded by an existing process and convert the heat into a productive end-use (Zhang et al., 2013). Indeed, it is estimated that from the total industrial energy consumption, approximately 20–50% of energy consumption is being discharged as waste heat (Johnson et al., 2008); specifically, for Southeast Asia, 40 Million ton of oil equivalent (Mtoe) energy is treated as waste heat out of the 79.7 Mtoe energy consumption of the total industry sector (IEA, 2015). Some of the waste heat is sometimes unavoidable and very hard to be recovered; however, WHR technologies could offer a valid solution to mitigate this waste heat. There are

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Nomenclature

CCGT	Combined Cycle Gas Turbine
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CO_2	Carbon dioxide
E_t	Electrical energy generated
F_t	Fuel expenditures
GDP	Gross Domestic Product
GHG	Green House Gas
HEORC	High Efficiency Organic Rankine Cycle
I_t	Investment expenditures
kW	kilowatt
kWh	kilowatt per hour
LCOE	Levelized Cost of Electricity
LEORC	Low Efficiency Organic Rankine Cycle
LPT	Low Pressure Turbine
M_t	Operation and maintenance expenditure
Mtoe	Million tonne of oil equivalent
MW	Mega watt
n	Lifetime
O&M	Operation and Maintenance
OECD	Organization for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
ORC	Organic Rankine Cycle
r	discount rate
SE	Steam Expander
SRC	Steam Rankine Cycle
t	year
TC	Turbo Compounding
TJ	Tera Joules
Toe	Tonne of oil equivalent
WHP	Waste Heat to Power
WHR	Waste Heat Recovery
YoY	Year over Year

several sources of waste heat in industrial sectors such as furnaces, ovens, turbines, engines, and other equipment (Outlook, 2010). This waste heat can be in the form of hot combustion gases discharged to the atmosphere, heated products exiting industrial processes and heat transfer from hot equipment surfaces (Fang et al., 2013; Karellas et al., 2013; Saidur et al., 2012; Zhang et al., 2013). Table 1 shows the temperature range and characteristics for several common industrial waste heat sources.

Among various industrial WHR technologies, Waste Heat to Power (WHP) is an important enabler. The basic principle of WHP is to utilize the waste heat to generate electricity. Recovering waste heat for thermal use (district heating, combustion air preheater, etc.) would always be the most economical and efficient way of using waste heat,where possible. However, most waste heat cannot be used for thermal use due to no localized heating or cooling requirements at the waste heat site; hence the use of WHP option to either use the electricity onsite or distributing it through the grid becomes a viable solution (Lecompte et al., 2015). In the context of Southeast Asia, there are some studies about WHP in different applications using different technologies. For instance, Rasul et al. (2005) point out that by using waste heat from kiln systems to dry raw metal and preheat combustion air, the cement industry in Indonesia can save around 1 million US dollars per year (Rasul et al., 2005); Yodovard et al. assess the power generation potential by using waste heat from diesel cycles and gas turbine cogeneration plants in Thailand; the estimated net power generation from these two sources using thermoelectric technologies is 100 MW (Yodovard et al., 2001); Popli et al. calculate that by using waste heat from oil refineries to drive absorption refrigeration chillers in gas turbine compressor inlet air cooling, around 3500MWh cooling energy can be saved per year in typical tropical climate (Popli et al., 2013). All these fragmented researches indicate the promising potential of WHP in Southeast Asia; however, an overall market potential estimate of WHP in this region still fails to be fulfilled. In addition to the techno-economic assessment of WHP technologies in the Southeast Asia region, the drivers and barriers that will shape the Southeast Asia WHP market together with the necessary conditions to successfully deliver a WHP project, are all meaningful research questions that merit to be explored. In such a context, this paper aims to achieve the following objectives:

- to get a quantitative estimate of WHP market potential in Southeast Asian countries;
- to identify the opportunities and drivers of WHP implementation in Southeast Asian countries;
- to investigate the factors that can make industrial WHP a success in Southeast Asian countries and make policy recommendation accordingly.

The remainder of the paper proceeds as follows: Section 2 introduces the working principle of common WHP technologies as well as economic and environmental assessment of WHP technologies; Section 3 analyzes the overall market potential of WHP technologies in Southeast Asia, as well as the potential drivers and barriers for WHP market expansion; Section 4 presents a promising power plant WHP

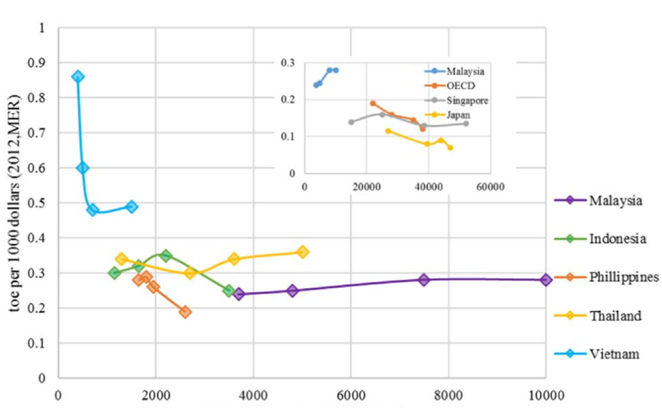

Fig. 1. Trends in energy intensity and GDP per capita in selected countries, 1980 – 2011 (ASEAN, 2015).

Table 1
Temperature range and characteristics for industrial waste heat sources.

Waste Heat Source	Temperature Range /° C	Cleanliness
Furnace or heating system exhaust gases	316 – 1100	Varies
Gas (combustion) turbine exhaust gases	480 – 600	Clean
Reciprocating engines	220–480	Clean
Jacket cooling water	90 – 100	Clean
Exhaust gases (for gas fuels)	480 – 600	Mostly Clean
Hot surfaces	65 – 316	Clean
Compressor after or inter cooler water	38 – 82	Clean
Hot products	100 – 1370	Mostly clean
Steam vents or leaks	120 – 316	Mostly clean
Condensate	65 – 280	Clean
Emission control devices – thermal oxidizers, etc.	65 – 816	Mostly clean