A PROPOSED METHOD TO EVALUATE COUNTRY'S ENERGY UTILIZATION EFFICIENCY

MIFTAHUL HUDA, NINING S. NINGRUM and RIDWAN SALEH
R & D Centre for Mineral and Coal Technology
Jalan Jenderal Sudirman 623 Bandung 40211,
Ph. 022 6030483, fax. 022 6003373
e-mail: huda@tekmira.esdm.go.id; ninings@tekmira.esdm.go.id; ridwan@tekmira.esdm.go.id

ABSTRACT

The threat of global warming should be addressed by increasing energy efficiency and reducing energy consumption, since the green house gas mainly comes from combustion of fossil fuel in energy sector. Unfortunately, the conventional energy efficiency indicator in national level such as energy consumption per capita (ECPC), energy intensity (energy consumption: gross domestic product (GDP)) and energy elasticity frequently shows a contradictory result. Energy consumption depends on both number of populations and GDP. Therefore, the energy efficiency indicator should also consider both parameters. The objective of this study is to develop a new energy efficiency indicator using both GDP and energy consumption per capita as parameters. In this study, a new energy efficiency indicator namely A/R energy is proposed. A/R energy (addition or reduction of energy) is calculated by subtracting the value of best practice ECPC with the value of actual ECPC. The value of best practice ECPC was derived from an equation correlated between ECPC and Gross Domestic Product (GDP) per capita. Using the new indicator, it is revealed that some country with low ECPC in Africa, Asia and South America should increase their ECPC while all the developed country should reduce their ECPC. The best practice correlation between best practice ECPC and GDP per capita was also used to evaluate energy projection of Indonesia. Indonesia energy projection has been developed by IEA, Green Peace and Indonesian Government. Considering GDP and population growth ECPC, it is concluded that Indonesia energy projection developed by IEA is the most realistic, efficient but achievable.

Keywords: energy efficiency indicator, best practice energy consumption, energy projection, energy elasticity

INTRODUCTION

Environmental issues from burning fossil fuel have appeared since industrial revolution. In the year 1800s, the issue was smoke coming from locomotive or boiler and in the year 1970s, acid rain caused by SO_2 and NO_2 from the combustion of fossil fuel became a major environmental concern. It is realized that both problems have been solved through implementing modification of technology or introducing new environmental friendly technology (Mc. Mullan, et al., 2001).

Currently, the world is facing global warming which threatens millions of people with an increased risk of hunger, malaria, flooding and water shortages. The global warming was caused by the increase of green house gas in the atmosphere. The most important Green House Gas (GHG), CO_2, is mainly (56%) comes from the use of fossil fuel (IPCC, 2007). Although the threat of climate change is real, the world energy up to 2050 seems to be dominated by fossil fuel (IEA, 2003). The world has been addicted by fossil fuels.

The present environmental issue, CO_2, is quite different with previous issue. The reduction of CO_2 to level which will not endanger the world cannot be solved by introducing new technology only, but also by suppressing the demand of fossil energy. Energy consumption is influenced by individual behavior, for instance, switching from private car to public transportation or using telephone call rather than visiting will reduce the use of energy as well as CO_2 emission (Markowitz and Doppelt, 2009). Therefore, public should be guided to participate in the all efforts to prevent climate change especially by reducing energy consumption.

The effort to increase energy efficiency and to reduce energy consumption may be enhanced through diffusion of knowledge to the public. They

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should realize how efficient their country in energy consumption by examining the energy efficiency indicator. Unfortunately, energy efficiency indicator in national level such as energy consumption per capita (ECPC), energy intensity and energy elasticity frequently shows a contradictive result. Therefore, a new simple energy efficiency indicator which informs public clearly should be developed. Hopefully, the public then will control the energy utilization efficiency in their country.

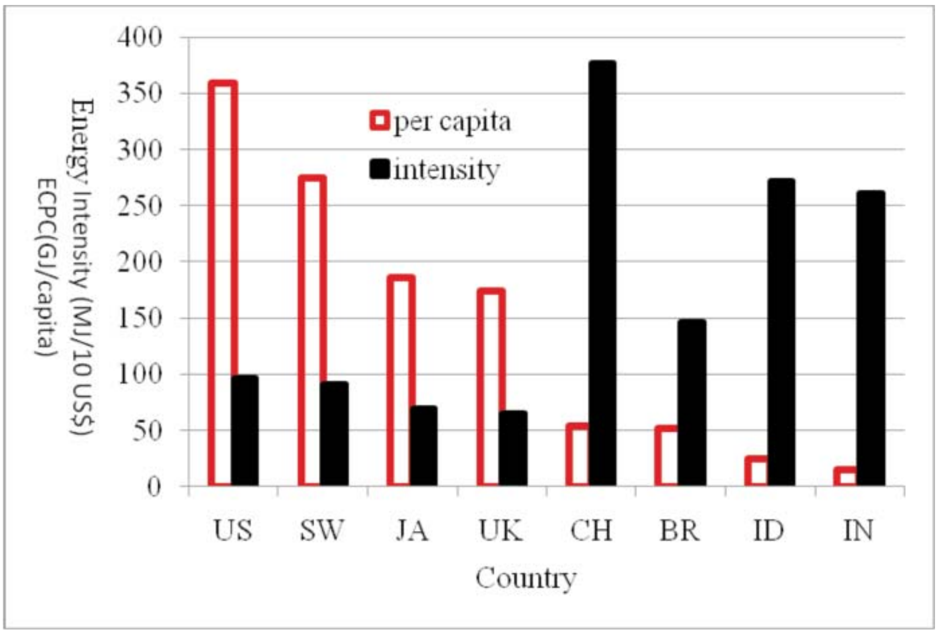
This study is aiming to develop a new indicator which gives clear information about efficiency of energy consumption. In addition, three available energy projection scenarios in Indonesia will be evaluated using the new indicator to select the most efficient, and achievable energy projection scenario for Indonesia.

Existing Method to Evaluate Energy Efficiency

Figure 1 illustrates energy consumption per capita (ECPC) and energy intensity of several countries. Energy consumption per capita is calculated based on total primary energy consumption divided by the number of population, while energy intensity is total primary energy consumption divided by Gross Domestic Product (GDP).

The energy intensity in the developed country such as United States (US), Sweden (SW), Japan (JA) and United Kingdom (UK) is lower than high populated developing country such as China (CH), Brazil (BR), Indonesia (ID) and India (IN), on the contrary energy consumption per capita is lower in the developing country than that of in the developed country. Thus the energy efficiency of developed and developing countries could not be compared by using both indicators.

Another parameter i.e. energy elasticity shows similar result; energy elasticity in developing country is higher than that of in developed country. However, it does not mean inefficiency since energy in developing country not only use to increase GDP, but also to fulfill basic need (lighting, cooking). The existing energy efficiency indicators may be suitable only for comparing energy efficiency among developed countries. As illustrated in Figure 1, it is obviously been that JA is more energy efficient than SW and US but less efficient than UK. For developing country, ID is more energy efficient than CH but less efficient than IN. However BR and IN could not be compared due to contradiction result between the value of energy intensity and energy consumption per capita of both countries. Energy scenarios are important in describing possible development



Notes: US = United States, SW = Sweden, JA = Japan, UK = United Kingdom, CH = China, BR = Brazil, ID = Indonesia, IN = India

Figure 1. Energy intensity and energy consumption per capita in several countries at 2005 (EIA, 2005).

paths, to give decision-makers an overview of future perspectives and to indicate how far they can shape the future energy system. Energy scenario is developed through complex calculation based on historical data, assumptions of some energy parameters (GDP, population, energy price, technology, etc), and correlation among the parameter to the energy consumption. The calculation of the scenarios usually was conducted by an expert using available computer software. Such a complex procedure did not allowed public to self calculated and evaluated the scenario. Therefore, a new and simple method to evaluate the scenario should be developed.

Energy intensity always follows a bell shape curve (Rühl, 2012). Depending on the progress of industrialization stage, the energy intensity increases at the beginning of industrialization to reach a peak and then decrease if the industrialization reaches a mature stage. Energy intensity of UK sharply increased from year 1800 to 1860 reached a peak at about 1875 and then gradually decreased to the current level. Energy intensity of US, JA and former Soviet Union (USSR) achieved peaks in the years 1925, 1960 and 1975, respectively (Vercelli, 2006). Thus, energy efficiency among countries cannot be compared using energy intensity as indicator, since each country experienced different stage of industrialization.

Evaluation of Energy Projection Scenarios; Case Study Indonesia's Energy Projection

Figure 2 shows Indonesia energy scenario estimated by the Government of Indonesia (GOI), International Energy Agency (EIA) and Green Peace (GP). The business as usual (BAU) scenario assumes GDP growth of 5.13% and 6.51% in the year 2010-2015 and 2020-2030, respectively and constant energy elasticity of 1.48. GOI scenario uses the same GDP growth as BAU scenario, however, energy elasticity gradually decreases to less than one by the year 2025. IEA scenario assumes annual economic growth of nearly 4% from 2002 to 2030. Total primary energy demand is projected to grow by 2.7% annually from 2002 to 2030. Under IEA Scenario, total energy demand will be more than double from the current 4,500 peta joule (PJ) /a to 11,300 PJ/a in 2050. The GP scenario has a target for the reduction of worldwide per capita carbon dioxide emissions to less than 1.3 ton per year by 2050 (Green Peace International and European Renewable Energy Council, 2007). This is prerequisite to stabilize global CO_2 concentrations at a level below 450 ppm under a global emissions trading scheme. As can be seen in Figure 2, at year 2025 GOI scenario predicts energy demand more than 15,000 PJ, while it is less than 7,000 PJ in the GP scenario. Such a big bias in estimation

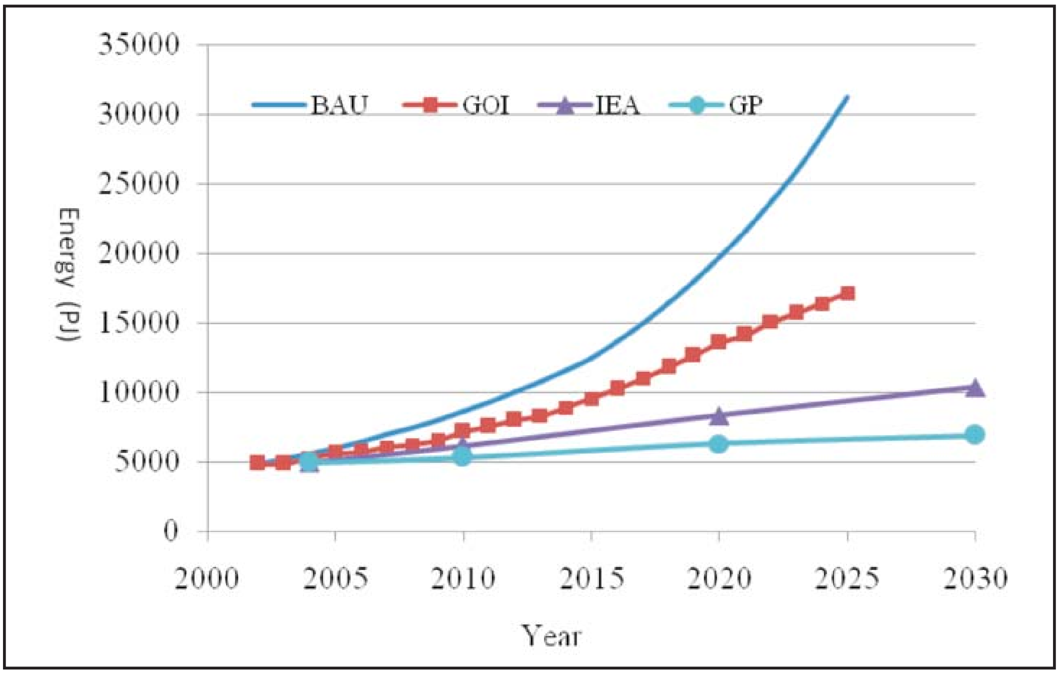


Figure 2. Indonesia's energy projection scenarios

results without comprehensive explanation may confuse the public.

METHODOLOGY

Energy consumption in a country depends on the number of population, GDP, energy price, climate and type of industry. However, population and GDP are considered to be the most influential factors to determine energy consumption. In this study, a correlation of energy consumption as function of GDP and population will be investigated to find "best practice" of energy consumption in each country. The difference between"best practice" energy consumption and actual energy consumption will be used as indicators of energy efficiency. In addition,"best practice" of energy projection of Indonesia will be developed and the result will be compared to the available Indonesia energy projection scenario in the country. All data used in this study were obtained from official energy statistic of the United States Government (EIA, 2005).

RESULTS AND DISCUSSION

Proposed Indicator for Energy Efficiency

Energy consumption correlates well with GDP and population. Basically, the more people there are, the more energy will be used, since everyone needs energy for daily life such as cooking, lighting and transportation. Similarly, the GDP, high amount of energy is needed to run industrial machines and apparatus in the industry. As a result, increasing GDP per capita always be followed by increasing energy use per capita. Figure 3 illustrates the correlation between actual energy consumption per capita (actual ECPC) and GDP per capita of nations in the world. Each filled circle represents energy profile of different country.

SW and US have almost the same GDP per capita. However, US is less energy efficient than SW since US experienced higher ECPC than SW. Denmark (DA) achieves more GDP/capita with less ECPC than US and SW. In general, high income country consumed energy per capita much more than that of low income country. Among high income country, Russia (RS), Saudi Arabia (SA) and Singapore (SN) are countries doing the poorest job in energy efficiency. Based on the data in Figure 3, world average ECPC is about 125 giga joule (GJ)/year.

It is reasonable to compare energy efficiency among countries using ECPC indicator, if the countries have almost the same GDP/capita. Solid curve in Figure 4 is proposed "best practice" correlation between GDP per capita and ECPC. The ECPC derived from the curve at given GDP per capita is called best practice ECPC. The curve is close to the value of actual ECPC of DA, UK, JA and Italy (IT), the most energy efficient high income country, suggesting that "best practice" ECPC proposed here is achievable.

The best practice correlation between GDP per capita and ECPC in Figure 4 is as follows:
GDP per Capita = Y. (best practice ECPC)^Z.... ....(eq.1)

where Y=2, Z=2, best practice ECPC is in Giga Joule per capita and GDP is in US$. One may select the other values of Y and Z, but we choose Y=Z=2, since it is considered to result in quite ideal, but achievable target of energy consumption per capita. Using equation 1, best practice ECPC at given GDP per capita can be calculated.

The energy efficiency indicator which is named here as A/R energy (addition or reduction of energy) is calculated by subtracting best practice ECPC (a) with actual ECPC (b) as follows;
A/R energy = ((a – b) x 100%)/b.............. (eq.2)

The value of A/R energy is positive, when the country needs an additional energy and minus when the country must reduce its energy consumption. The A/R energy of each country is listed in Table 1.

Using the best practice equation developed, it is revealed that among developed country, DA is the most energy efficient country, which only has a decrease of 4% of its ECPC. It is quite reasonable since DA is a country with the highest percentage of combined heat and power in Europe with 50% of its electricity is supplied by high efficient of cogeneration plant (Danish Energy Authority, www.energy.rochester.edu/dk/manczyk/denmark.pdf).

China should decrease its ECPC about 46%. Energy used in China has been increasing much more rapidly than the growth in GDP. For example,

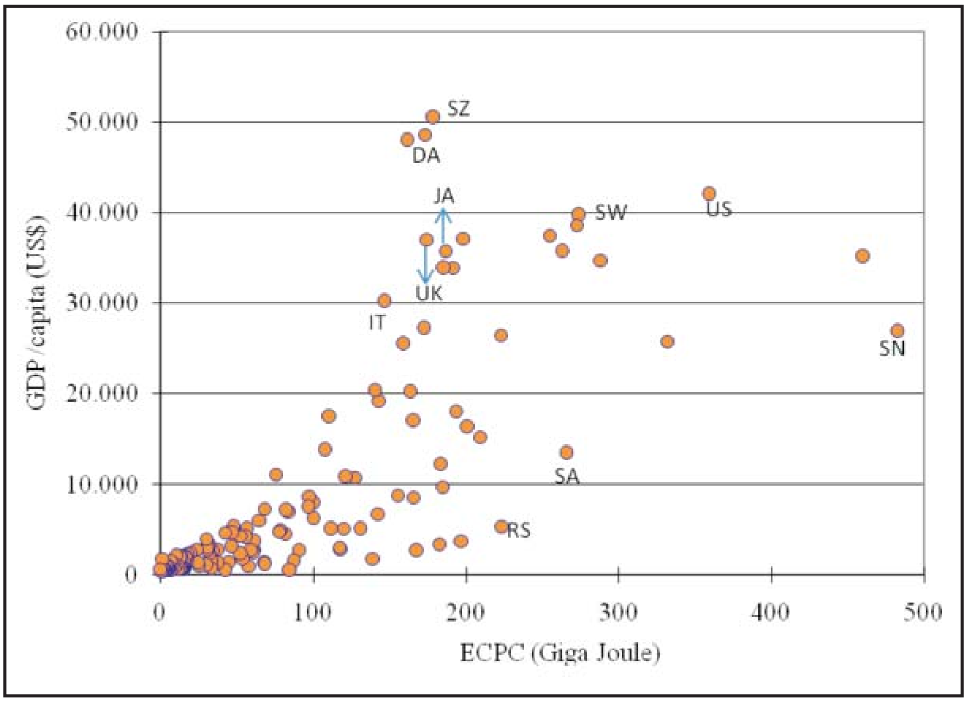


Figure 3. Correlation between GDP per capita and ECPC

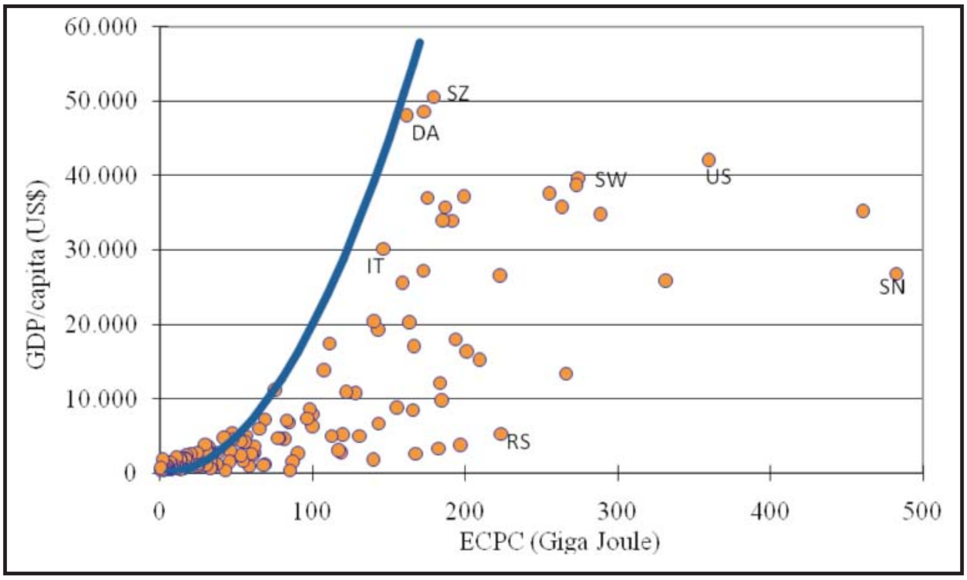


Figure 4. Best practice correlation between GDP per capita and ECPC

China is currently installing the equivalent of a 1000 MW coal fired power plant each week and generating capacity comparable to the entire UK electricity system each year. The actual ECPC of country in Middle East has been directly influenced by the level of oil production to result in large difference in actual ECPC between oil producer countries such as Kuwait, UEA, Saudi Arabia and small or no oil producing country such as Yemen.

Interestingly, energy efficiency of BR and IN, their energy efficiency could not be compared using conventional indicator (Figure 1) showing different

Table 1. Add-red energy of several country

Country	A/R (%)	Country	A/R (%)	Country	A/R (%)	Country	A/R (%)
Haiti	345.3	Switzerland	-11.2	Syria	-40.2	Seychelles	-60.5
Sudan	344.1	Brazil	-12.2	Romania	-41.8	Venezuela	-61.7
Kenya	199.8	Algeria	-15.0	Mongolia	-42.4	Djibouti	-62.1
Senegal	167.1	Portugal	-15.7	Antigua	-42.6	Estonia	-62.3
Ghana	124.2	Italy	-16.2	Bosnia	-43.1	Norway	-62.7
Nigeria	110.3	Georgia	-18.7	E. Guinea	-44.3	Paraguay	-63.0
Swaziland	93.0	UK	-22.2	Slovenia	-44.5	Kyrgyzstan	-63.7
Guatemala	88.9	Chile	-27.8	China	-46.1	Armenia	-65.0
El Salvador	76.5	Greece	-28.2	Finland	-46.3	Brunei	-65.8
Morocco	62.6	Japan	-28.4	N. Zealand	-48.4	Belarus	-66.8
Nicaragua	51.4	Germany	-29.9	Sweden	-48.6	Iceland	-68.6
Philippines	50.6	Latvia	-30.4	Netherlands	-49.0	Iran	-68.6
Honduras	41.5	Israel	-31.6	Belgium	-49.2	Azerbaijan	-68.7
Yemen	31.3	Spain	-32.3	Bahamas	-50.9	Saudi A.	-69.2
Pakistan	27.5	Croatia	-32.8	Australia	-54.3	Canada	-71.2
India	20.1	Egypt	-32.8	Korea, South	-55.1	Singapore	-76.0
Colombia	18.7	Jordan	-35.6	Malaysia	-55.2	Russia	-76.9
Vietnam	13.6	Lithuania	-36.9	Luxembourg	-56.0	T. menistan	-77.4
Uruguay	7.6	Poland	-37.1	Slovakia	-57.4	Kazakhstan	-78.1
Indonesia	2.5	Argentina	-37.4	Czech Rep.	-57.5	Oman	-78.3
Costa Rica	1.6	Moldova	-38.4	South Africa	-57.9	Kuwait	-78.3
Tunisia	0.1	Cyprus	-38.5	Taiwan	-58.3	Ukraine	-78.7
Denmark	-4.1	Thailand	-38.8	Libya	-59.5	U. Arab E.	-80.2
Ireland	-9.9	Macedonia	-39.3	US	-59.7	Uzbekistan	-82.4
Turkey	-11.2	Hungary	-39.5	Suriname	-60.0	Qatar	-86.1

value of A/R energy. BR should decrease their actual ECPC about 12%, while IN may increase their actual ECPC to 20%.

If each country follows the best practice ECPC, the average ECPC in the world is 46 Giga Joule/capita, which is considerably low compared to average actual ECPC in the world of 125 Giga Joule/capita. Such a low consumption of energy may prevent the climate change to occur.

Evaluation of Energy Projection Using Best Practice ECPC, Case Study; Indonesia Energy Projection

Using equation 1 {GDP per capita = 2. (best practice ECPC)^2}, best practice ECPC can be calculated at given GDP per capita. If the GDP and population growth in the future can be estimated, the future best practice ECPC can be calculated. Then, the annual energy demand of energy of each country in the future can be calculated by multiplying best practice ECPC and the number of population at given year.

In the year 2007, the GDP of Indonesia was 344.042 billion US$ (IMF, 2006) and the number of population was 224.227 million or the GDP/capita was 1534 US$. If GDP and population growth were 6% and 1.2%, respectively, in the year 2030 Indonesia GDP/capita will reach 4,455 US$. Using the equation 1, the best practice ECPC in the year 2030 should be 47.2 GJ/capita. The annual demand of energy in the year 2030 calculated by multiplying best practice ECPC with the number of population will be 13,922 PJ (Table 2).

Table 2. Calculation result of energy projection when GDP growth of 6% and population growth of 1.2%

Year	Population (million)	GDP (billion US$)	GDP/capita US$	Energy Demand	
				per capita (GJ)	annual (PJ)
2007	224.2	344.0	1534.3	27.7	6210.6
2008	226.9	364.7	1607.1	28.3	6432.5
2009	229.6	386.6	1683.3	29.0	6662.3
2010	232.4	409.8	1763.2	29.7	6900.2
2020	261.8	733.8	2802.5	37.4	9801.6
2030	295.0	1314.2	4454.6	47.2	13922.9

The calculation result of Indonesia energy projection at various GDP and population growth was plotted in Figure 5. GDP6P12 curve is result of the calculation when GDP growth of 6% and population growth of 1.2%. As can be seen in Figure 5, the GOI energy projection is still above the GDP6P12 projection scenario calculated using the equation 1, suggesting the GOI projection is overestimated. The IEA energy projection for Indonesia is almost coincided with GDP4P12 projection. However, GP energy projection could not be approached even by GDP2P03 scenario. The GDP growth of 2% and population growth of 0,3% is considered very low for Indonesia. It seems that IEA energy projection is more reasonable than that of GOI and GP for Indonesia.

CONCLUSION

Conventional energy efficiency level indicators such as ECPC, energy intensity and energy elasticity frequently show ambiguous results. A country with high GDP/capita usually shows low value of energy intensity and energy elasticity, on the contrary densely populated country with low GDP/capita shows low value of energy consumption per capita. Thus, the conventional indicator cannot be used to compare energy efficiency among the countries, since each country has different amount of GDP, number of population and progress of industrialization. We have developed a new indicator namely A/R energy, as an alternative to the conventional one. A/R energy

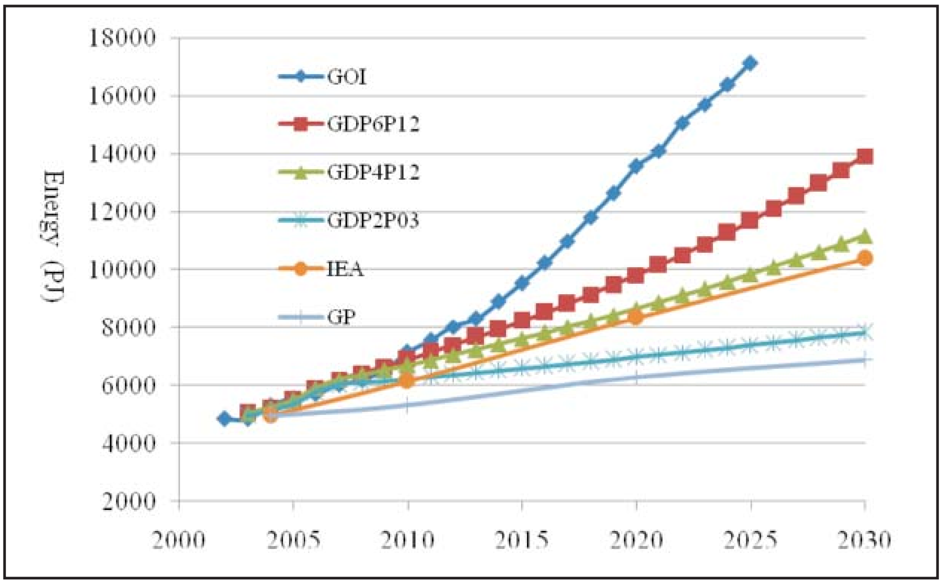


Figure 5. Energy projection calculated by best practice correlation of ECPC and GDP

(addition or reduction of energy) is calculated by subtracting the value of best practice ECPC with the value of actual ECPC. The value of best practice ECPC was derived from an equation correlated between ECPC and GDP per capita. Using the new indicator, it is revealed that some countries with low ECPC in Africa, Asia and South America should increase their ECPC, while all the developed country should reduce their ECPC. BR and IN, which their energy efficiency could not be compared due to contradiction result of energy intensity and energy consumption per capita shows different value of A/R energy. BR should decrease their actual ECPC about 12%, while IN may increase their actual ECPC to 20%. The best practice correlation between best practice ECPC and GDP per capita was also used to evaluate energy projection of Indonesia. The IEA energy projection is considered to be the most realistic energy projection for Indonesia.

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