Waste as fastest cycle of renewable energy sources through TOSS Model

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Abstract. Natural fossil formation takes several million years while coal consumption trends to be higher from time to time. Such unbalance condition leads to the faster decreasing reserve of oil, gas, and coal that will create various impacts for people in the future since they will have no fossil energy anymore. Therefore, many countries in the world make an effort to use various biomass as renewable energy sources alternatives. Unlike intermittent sources such as solar, wind, or tidal energy that cannot be stored, biomass can be renewed and storage as similar to fossil fuel. However, it takes million decades to create fossil fuel like coal, gas, and oil, while biomass can be renewed in much shorter cycle. For examples, wooden biomass from natural forest or jungle will take around ten years cycle to grow, forest woods from cultivated plantation will take around five years cycle, and some kind of biomass take less than a year renewable cycle such as rice husk, straw, vetiver grass, and other cultivated plantation. Waste as a focal point of this study is a biomass with a shortest renewable cycle because human, animal, and plant produced waste continuously and its population is always increasing. STT PLN school of technology Jakarta has conducted study and pilot project to convert waste into pellet or briquette that can be used to replace coal, gas, or oil. This waste to energy model that takes only less than ten days to produce pellet from fresh waste is named TOSS, stand for tempat olah sampah stempat, means localized waste treatment. Therefore it can be stated that renewable cycle of waste, particularly municipal waste is only ten 10 days cycle. By using this renewable cycle approach, any kind of biomass value can be compared to the value of coal over certain period of time. For instance, 1000 ton of waste can be converted into at least 100 kg with 3000 kcal/kg equivalent pellet in 10 days. It means that 1000 ton of waste in only 100 days is equivalent to 1000 ton of low rank coal that takes million years to formed.

1. Introduction

1.1. Indonesia energy supply and consumption
The increasing of population as well as the national economic growth has increased electricity consumption. On the other hand, Indonesia is still relying on fossil fuel to serve this demand and according to the national electricity business plan 2018-2027, the energy mix in Indonesia is dominated by coal as shown in Table 1. It can be shown that coal will still dominate the power plant energy mix until the next ten years, while other sources are limited and a lot of renewable energy potential has not been utilized. The coal potential resource projection up to 2016 is around 128 billion tonnes while its proven deposit reserve is 28.4 billion tonnes. On the other hand, the national annual...
coal consumption projection of coal is 400 million tonnes and 100 million tonnes of which is used for Coal Power Plant [1]

Table 1. National fossil fuel demand projection for power plant used

| Fuel  | Unit  | 2018  | 2019  | 2020  | 2021  | 2022  | 2023  | 2024  | 2025  | 2026  | 2027  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Gas   | TBTU  | 520   | 604   | 622   | 561   | 593   | 601   | 613   | 687   | 686   | 727   |
|       | T kCal| 131   | 152   | 157   | 141   | 149   | 151   | 154   | 173   | 173   | 183   |
| Oil   | TkL   | 3105  | 3085  | 1915  | 987   | 473   | 492   | 514   | 510   | 526   | 553   |
|       | TkCal | 0.80  | 0.80  | 0.49  | 0.25  | 0.12  | 0.13  | 0.13  | 0.14  | 0.14  | 0.14  |
| Coal  | Mton  | 92    | 96    | 106   | 120   | 128   | 136   | 144   | 130   | 145   | 162   |
|       | TkCal | 368   | 384   | 424   | 480   | 512   | 544   | 576   | 520   | 580   | 648   |

If the consumption rate remain constant, coal will be lasted in 70 years. The next available fossil fuel is natural gas as Indonesia has estimated around 144 TSCF (by January 2016) but only 101.22 TSCF is proven and 42.84 TSCF of which is potential. By 2016, the national average annual gas production is only 3 TSCF. The demand gas projection by 2025 is 9,121 MMSCFD, one third of this is used for power generation with 2361 MMSCFD contracted, means that Indonesia should import gas at latest by 2019 [1].

1.2. The problem to be addressed

Natural fossil formation may take hundred million years while consumption trends to be higher from time to time. Such unbalance condition leads to the faster decreasing reserve of oil, gas, and coal that will create trouble for people in the future since they will have no fossil energy anymore. To overcome the problem, many countries make an effort to use various renewable energy sources alternatives such as geothermal, hydro power, solar, wind, and biomass energy. However, this study will focus on biomass as renewable energy that can be renewed in periodic cycle by human including wooden forestry, biomass from ricefields and other agro plantation and municipal waste. Waste is the less expensive biomass but the current available waste to energy practices are relatively expensive and the process is still rely on large scale waste processing at landfill. There is another most common practice to use biogas from waste by anaerobic digesting principle, but this model produces only small amount of energy form methane gas and left a huge amount of nondegradable waste.

In other to make the waste to energy more effective, STT PLN, the School of Technology Jakarta, has conducted study and pilot project to find the simple and friendly method to convert municipal waste to become biocoal in the form of pellet or briquette. This process has a brand name TOSS taken from Indonesian abbreviation meaning local waste processing unit using simple technology that can be undertaken by common people. TOSS is a name that cannot be translated like that of Kaizen and Osaki from Japan. The first TOSS pilot project at Klungkung area Bali has successfully produced waste biocoal in the form of briquette or pellet, which is easily packaged and transported. Compare to other biomass from wood or plantation, waste pellet should be cheaper and much more easier to produced. Waste pellet can be produced in 10 days, much faster than those biocoal from agriculture product that need several months to be harvested. This study will conduct simulation to show that thru the TOSS process, waste is the fastest cycle of renewable energy sources, compare to other renewable energy sources.

2. Literature Review

2.1. Fossil: renewable vs. sustainable

Although fossil fuels are created from the organic matters such as trees that can be planted or renewed, it is not considered renewable because the rate of fossil fuel consumption is much more higher than the rate of reproduction. But fossil fuel can be sustainable if we can control the limit of exploitation and consumption and balance it with other energy sources. Many experts belief that fossil fuel including coal cannot be sustained if people are still consuming it as usual [2]. On the contrary, even
renewable resources can become unsustainable if a resource is used up faster than it can regenerate and it will eventually be entirely depleted despite its renewability. Conversely, a non-renewable resource can be sustainable if it's used in moderation. In addition, if used without caution, these can be depleted in a short time [2]. By 2012, these dense supplies of fossil energy provided 87 percent of global primary energy consumption, and mostly used for the power generation, home heating, and transportation purposes [3].

Fossil fuels including oil, gas, and coal are natural energy sources which are made from dead organisms through the geological processes over the period of hundred million years. Most researchers agree that a massive and widespread of coal deposits were formed in carboniferous period of the Paleozoic around 300 million years ago. Lignin is a major component of the woody tissue that modern tree trunks are made of. It is tough for most organisms to eat, except for the white rot fungus that lives on dead trees. White rot fungi break down the lignin in wood, leaving the lighter colored cellulose behind, some of the break down both lignin and cellulose [4, 5].

Compare to other fossil fuels, coal has the largest available reserve in the form of a rock, which is mainly composed of carbon and other elements. Coal was formed from the plants decomposition that has a high energy potential, which is useful for both electricity generation and heating purpose [2]. The ultimate energy source of coal is the sun because the energy stored within dead plant matter is what yields coal[4]. The older is the coal maturity, the higher the energy content, begin with the highest Anthracite (31-36 MJ/Kg), Bituminous (25-34 MJ/Kg), Sub-bitumonous (19-30 MJ/Kg), and the lowest Lignite (12-19 MJ/Kg. Until recently, the electricity cost of coal power plant is the lowest compare to other power plant, ignoring the cost of externalities including environmental and social impact. The total reserve of coal as per 2012 is around 10^{12} tonnes, where the United States is the largest, and coal exhibits a 109 year reserve to production ratio, means that from today, coal will be lasted in the next hundred years [5].

Despite the fact that coal is the less expensive, most available reserve, and most energy effective, coal is responsible for more emissions of carbon dioxide compare to any other fossil fuel. Coal is burned with the presence of oxygen in the atmosphere, which allows a chemical reaction between the carbon and the oxygen to form Carbon dioxide (CO_2). The production of CO_2 harms the environmental that leads to climate change. Evenworst, most coal contains large polluted elements including sulfur, mercury, and sometimes lithium and burning coal also causes the formation of both NO_x and SO_x [3, 5]. There are many other environmental impact in exploiting fossil fuel, beyond the burning of these fuels. Some of those are the habitat destruction during mining or excavation, loss of bio-diversity, and water pollution. Many countries show their concern about the impact of fossil fuel to the global climate and they have agreed to take effort in reducing environmental impact of fossil fuels by putting the mandatory pollution control in their legislation. More and more countries and environmental practitioners are concern about the utilization of biomass as coal substitution with almost zero CO_2 emission.

2.2. Renewable energy (RE) that can be renewed
In the new millenium, the impact of climate change and global warming will be seriously threatening our earth. Therefore, renewable energy (RE) will become important factor that may halt global warming and to promote sustainable development [5]. However, the challenge to develop RE sources is becoming increasingly problematic. For instance, hydro and geothermal are RE that have large reserve potential but this kind of RE are naturally given and human has minor control to renew it. More over, currently, the exploitation of large hydro power plant and geothermal are often conflicting with social and environmental issues because many hydropower project has to remove a huge area including forest with its animals and many villages to be filled by water. Similarly, a lot of geothermal plants in Indonesia are located in the middle of the tropical jungle or forest that needs to be conserved. On the other hand, there are easily available RE such as solar, wind, or tidal but this kind of RE sources are hard to control because they could not be renewed or recreated by people. In addition, the current technology for this kind of energy are still facing intermittency problems and need to be supported by the expensive battery or other energy storaged.
Therefore, the aim of this study is to propose the use of RE that can really be renewed by human effort, which is biomass. Unlike the natural given biomass like hydro, geothermal, sun, wind, and tidal, biomass is the type of RE that can be intentionally renewed or produced by people. For example, industrial forestry can be cultivated and harvested in 3 to 5 years, ricefields and agro plantations can be planted in less than one year cycle harvesting period. But the easiest and the fastest RE cycle of renewal is waste including human waste, animal waste, and waste from any cultivated and wild plants. This study will show that people can produce biofuel from waste in less than 10 days by using TOSS (a brand name) as a result of STT PLN study and pilot project that has been implemented at Klungkung area, Bali since the beginning year of 2017.

2.3. Biomass as renewable energy that can be renewed

Unlike intermittent sources such as solar, wind, or tidal energy that cannot be stored, biomass can be renewed and storage similar to fossil fuel but it takes in much less cycle of renewal compare to that of fossil fuel that need million decades to create coal, gas, or oil. For examples, wooden biomass from industrial forestry will take around five years cycle to grow and some kind of biomass from agricultural plants such as rice husk, straw, vetiver grass take only less than a year cycle.

Most author define biomass as energy derived from natural materials such as wood, agricultural waste, marine algae, grass, microalgae, forestry waste, organic components from industry and households and animal and human waste [6, 7]. Shuit S.H. et.al. also depicted that biomass from oil palm industries will be the most promising alternative as a source of renewable energy [8]. Another author depicts that biomass resources including wood and wood wastes, agricultural crops and their waste byproducts, municipal solid waste, animal wastes, waste from food processing and aquatic plants and algae [9]. The next study of biomass was conducted by Hofsetz et. al., who analyzed and estimated the quantity of sugarcane bagasse to be used for energy & non-energy consumption for second-generation ethanol for 2015 and 2030 [10]. Further research was conducted to study a feedstock from the second generation of bioethanol from sugarcane bagasse and trash. It was found that the second generation ethanol may be potential to compete with electricity production from the lignocellulosic fraction of sugarcane. Second generation ethanol may favorably compete with bioelectricity production when sugarcane trash is used and when low cost enzyme and improved technologies become commercially available [11]. Lately much attention has been focused on identifying suitable biomass species, which can provide high-energy outputs, to replace conventional fossil fuel energy sources.

Biomass is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities. The conversion technologies for utilizing biomass can be separated into four basic categories: direct combustion processes, thermochemical processes, biochemical processes and agrochemical processes [9]. The type of biomass required is largely determined by the energy conversion process and the form in which the energy is required. Fuel for electricity generation derived from organic material in the form of organic waste or certain plants suitable for power plants such as Kaliandra, Sugar Cane, Corn, Velvier and others. microbial fuel cells (MFCs) have gained a lot of attention in recent years as a mode of converting organic waste including low-strength wastewaters and lignocellulosic biomass into electricity. Microbial production of electricity may become an important form of bioenergy in future because MFCs offer the possibility of extracting electric current from a wide range of soluble or dissolved complex organic wastes and renewable biomass [12]. However, in the future, energy crops will be one of the promising biomass that makes it possible to make large-scale energy plantations.

2.4. Biomass in Indonesia

Indonesia as an agricultural country has considerable biomass energy potential. It is estimated that the potential of all biomass energy is equivalent to 49.8 GW. However, as seen in Table 2, the contribution of the biomass energy potential is very small, compared to other RE sources.
Table 2. Renewable Energy development plan in Indonesia

| No | RE Plant       | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|----|----------------|------|------|------|------|------|------|------|------|
| 1  | Geothermal (MW)| 210  | 150  | 221  | 235  | 405  | 445  | 355  | 2537 |
| 2  | Hydro (MW)     | 66   | 287  | 193  | 755  | 315  | 196  | 635  | 4461 |
| 3  | Microhydro (MW)| 108  | 202  | 366  | 103  | 31   | 41   | 19   | 235  |
| 4  | Solar (MWp)    | 3    | 47   | 214  | 281  | 200  | 300  | 635  | 4461 |
| 5  | Wind (MW)      | 70   | 60   | 5    | 45   | 10   | 30   | 309  |      |
| 6  | Biomass (MW)   | 53   | 53   | 41   | 19   | 235  |      |      |      |
| 7  | Biofuel (Th. KL)| 607  | 598  | 375  | 217  | 146  | 150  | 154  | 157  |
|    | Total (MW)     | 510  | 799  | 1040 | 1438 | 996  | 871  | 1299 | 7298 |
3. RE cycle simulation

3.1. Biomass cycle period comparison
This study will propose the cycle period comparison among various type biomass by using coal energy equivalent period. For examples, wooden biomass from natural forest or jungle can be renewed in five to ten years cycle, woods plantation and oil palm will take around five years cycle, and there are some biomass with less than one year cycle such as rice husk, straw, vertifer grass. Waste is the type of biomass which automatically renewed in a daily cycle produced by every people and the result of STT PLN study that can produce pellet for fuel in less than 10 days by using TOSS model, it means that waste is the fastest cycle of biomass renewable period.

Simulation will be based on the following assumption:
1. Unit area of land that can be used to produce agro and forest biomass is per 1000 ha
2. Human waste production is 0.5 kg/individual
3. Waste from tree and agricultural remains is 10% of the no 1 product
4. Biomass is grouped according to the following cycle of production:
   - Group I: Five years cycle (e.g. forestry wood, palm, industrial plantation and alike)
   - Group II: One years cycle (e.g. sugar cane, wild woods)
   - Group III: Six months cycle (e.g. Kaliandra, Jarak and other cultivated plants)
   - Group IV: Four months cycle (e.g. ricefields, corn, wheat, wildbush)
   - Group V: Ten days cycle for briquette made from human waste, animal waste, and waste from crop and tree remains
5. Briquette or pellet made from waste production is 10 days, based on STT PLN study

3.2. Example of Biomass potential calculation:
A community area with 1 million people is potentially produces group I biomass of 1000 ha, group II of 500 ha, group III of 2,000 ha, and other biomass from group IV of 2,500 ha. Howmuch is the equivalent coal biomass capacity and energy of this community?

For simplicity, the biomass potential capacity per area are the following: Group I: 100 ton/Ha, Group II: 50 ton/Ha, Group III: 20 ton/Ha, Group IV: 20 ton/Ha. For waste biomass (group V) it is assumed that people produce 0.5 ton of waste per 1000 people. Coal energy: 5000 kCal/kg.

The biomass equivalent coal capacity potential per n year is calculated by the following equation:

\[ B_n = c_n f k p, \quad \text{(in ton)} \]

To calculate the energy potential total of n year, the following equation is used:

\[ E_n = B_n e, \quad \text{(in Mcal)} \]

where
- \( c_n \): Biomass cycle per n year
- \( p \): Biomass production per cycle (ton)
- \( e \): Biomass energy estimate (kCal/kg)
- \( k \): Waste to pellet weight ratio
- \( f \): Biomass to Coal energy ratio

The calculation of Bn and En for each type of biomass can be seen in Table 3. The result shows that although type V, which is waste biomass, produces the smallest unit per cycle, the total result of both volume and energy potential is much larger than other type of biomass. From the above calculation, it can be seen that waste can be the fastest renewable cycle of biomass if it is processed by TOSS model. Therefore, waste is highly potential for coal substitution and the government should pay special attention to replicate TOSS model across the nation by involving local people under the coaching of its local universities.
**Table 3.** Illustration of Biomass energy potential

| Biomass category | $c_s$ | Area (Ha) | Prod/Ha (ton) | $p$ (Ton) | $e$ (kCal/kg) | $k$ | $f$ | $B_s$ (Ton) | $E_s$ (GCal) | $E_s$ (GWh) |
|------------------|------|-----------|--------------|----------|--------------|----|----|------------|-------------|-------------|
| Type I           | 1    | 1,000     | 100          | 100,000  | 4000         | 2  | 0.9| 60,000     | 243,000     | 283         |
| Type II          | 5    | 500       | 50           | 25,000   | 3500         | 2  | 0.7| 48,611     | 119,097     | 139         |
| Type III         | 10   | 2,000     | 20           | 40,000   | 3500         | 2  | 0.7| 140,000    | 343,000     | 399         |
| Type IV          | 15   | 2,500     | 20           | 50,000   | 3500         | 3  | 0.6| 180,000    | 324,000     | 377         |
| Type V*          | 180  | 1,000     | 100          | 100,000  | 4000         | 2  | 0.9| 60,000     | 243,000     | 283         |

Total biomass potential (ton) : 644,611 ton
Total biomass energy (GWh) : 1,649 GWH

*1 million people and 0.5 kg waste/person

### 4. Conclusion

Biomass is the renewable energy source that can be renewed by people effort that can be easily convert to produce biocoal as coal substitution. The STT PLN study and pilot implementation of municipal waste to pellet using the concept of local waste processing unit, namely TOSS shows that it takes only less than 10 days to produce pellet from fresh waste.

The result of TOSS innovation has made waste as the fastest cycle of renewable energy formation. Waste in this context does not only mean waste from human but also waste from animal all kind of agricultural waste as well as forest waste. The simulation example for 5 years period shows that from 6,000 Ha of land for biomass proves that utilization various biomass including waste may potentially add MW renewable energy potential.

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