Electricity machinery, renewable energy and green economy

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Abstract. The increase in industrial activities is followed by an increase in complex environmental problems, such as air pollution due to factory exhaust fumes, which are mostly produced in industrial areas such as in Surabaya, Indonesia. Based on data from iqair.com, three industrial areas in Surabaya fall into the category of moderate to unhealthy sensitive groups. The Tandes industrial area is in the unhealthy category for sensitive groups with an AQI index of US 104. Meanwhile, Kertajaya and Benowo are in the moderate category with US AQI indexes of 61 and 86 respectively. It is necessary to implement a green economy program. The existing renewable energy power plants in Indonesia will support the industry to switch to the use of electricity-based machines from renewable energy which will reduce air pollution that causes greenhouse gas emissions. The purpose of this study is to analyze the factory environment and application of a green economy through the use of electricity-based machines. Qualitative method is employed in this study. The results showed that the application of electricity-based machines can reduce the level of air pollution in Surabaya and potentially increase renewable energy in Indonesia.

1. Introduction

The industry is growing impressively in the Industrial Revolution 4.0 and Society 5.0 which mostly are influenced by use of technology. Country can be categorized as a developed if industry as a main sector in that country. Therefore, Indonesia as a developing country continues to develop the industrial sector to move as the developed country.

Industry is one of the sectors that provide the largest contribution to national income. Ministry of Industry in a press release on July 18, 2021 conveyed that there was an increase in the processing industry by USD81.07 billion (33.45%). Moreover, the processing industry presents the largest contribution nearly 78.80% of the total national exports or USD102.87 billion [1]. In the pandemic pressure, exports of this industry still increased by 9.7% from May to USD14.08 billion. With this number of exports, the processing industry contributed 75.91% of the total national exports or USD 18.55 billion. On the other hand, the manufacturing industry contributes to national income through export performance as well. In June 2021, iron and steel industry exports realize of USD 1.99 billion, animal/vegetable fats and oils USD 1.89 billion, electrical machinery and equipment USD 1 billion, vehicles and parts USD 734.6 million, and rubber and rubber products reached USD 605 Million [1].

On the other hand, advanced industry brings negative impact on the environment. Expansions in industrial activities are followed by increasingly complex environmental problems, such as air pollution due to factory exhaust fumes and vehicle emission. IQAir release the average air quality in Indonesia in 2020 reach out 114 and is classified as unhealthy for sensitive groups. Meaning that the...
concentration of PM2.5 in Indonesia is currently four times above by the WHO recommendation. As a consequence, Indonesia is ranked 9th out of 106 countries in the world. In 2020, South Tangerang is the most polluted city in Indonesia with an AQI of 161, while Palangkaraya is the cleanest city with an index of 24 [2]. Moreover, higher AQI in Surabaya comes from existing industrial areas such as SAQI – Benowo, RespoKare Mask – Kertajaya, SAQI – Keputih, and Surabaya Tandes.

Since the 1970s, the government has begun to develop industrial estates in East Java. In that period, East Java continued into the largest business center in eastern Indonesia. Surabaya Industrial Estate Rungkut (SIER) established in 1974 is the first industrial area in East Java that was built on an area of 245 hectares in Rungkut. After eleven years, SIER expanded into the Berbek with an area of ±87 hectares. Beside that, Surabaya also has other industrial areas such as Benowo, Kertajaya, Keputih, and Tandes as well as Sidoarjo Rangkah Industrial Estate (SiRIE) and Safe n Lock. Most industries still use engine-based technology by steam or diesel energy (boiler). Utilization of boiler machine is one of the causes of increasing air pollution in Surabaya.

Coal boilers are one of the sources of air emissions released through the chimney. These emissions contain several pollutants of particulates (dust) or gases such as NO₂, CO, CO₂, and SO₂. In addition, another environmental issue that needs to be considered is Greenhouse Gas (GHG) emissions which have a direct or indirect effect on the greenhouse effect that causes climate change. In the UN convention on climate change, there are six types of gases classified as GHGs, namely carbon dioxide (CO₂), methane (CH₄), nitrogen oxides (N₂O), sulfur hexafluoride (SF₆), perfluorocarbons (PFCS), and hydrofluorocarbons (HFCs). Furthermore, carbon monoxide (CO), nitrogen oxides (NOx), chlorofluorocarbons (CFCs), and volatile non-metallic organic gases are also included in GHGs [3].

As a consequence, further handling is needed regarding the use of fossil fuel or non-renewable energy. The Indonesian government has begun to change its strategy by focusing on applying renewable energy. This is because Indonesia has great potential for renewable energy from solar, water, wind, geothermal, and bioenergy. Through the US Power Working Group Forum, Dadan Kusdiana as Director General of New Renewable Energy and Energy Conservation stated that Indonesia's total geothermal potential is more than 400 GW, wind and hydro potentials are 150 GW each [4]. The New Renewable Energy (NRE) potentials are absorbed through the construction of power plants. Currently, Indonesia has six types of power plants, which are water, steam, gas, diesel, geothermal, and renewable energy with all power plants with a capacity of 70,964 MW as of June 2020 [5].

Based on the press release of the Ministry of Energy and Mineral Resources Number 122.Pers/04/SJI/2020, Indonesia already has 64,620 solar panels located in Wineru, East Likupang, North Minahasa, Province of North Sulawesi. On the other hand, East Java already has the largest hydropower plant, namely the Sutami hydropower plant in the Karangkates reservoir. It is possible for the industry to switch to the use of electricity-based machines with the number of renewable energy power plants that already exist. Moreover, current climatic conditions which tend to be hot and windy support for utilization of renewable energy. As a result, diminish air pollution that causes greenhouse gas emissions.

To sum up, this study aims to analyze the impact of factory exhaust fumes on the environment and analyze the application of a green economy through the use of electricity-based machines based on the potential of renewable energy in Indonesia.

2. Research methodology

This study employs a qualitative method or artistic method because the research process is more artistic (less patterned). This method also mentioned as an interpretive method since the result is more related to the interpretation of the data [6]. The data is mostly of words that come from various primary and/or secondary sources. There are three essential steps in qualitative analysis, which are data reduction, data display, and drawing conclusion [7]. Population is referred to social situation which consists of three elements, namely place, actors, and activity [6]. Cluster sampling method, which is part of probability technique, is conducted in this study. Surabaya industrial area is elected
for the sample. Data are collected from the articles, books, government websites, and policies and government regulations. In addition, data is described and explained using Miles and Huberman model. Figure 1 shows the social situation in this study.

![Diagram showing social situation](social_situation.png)

**Figure 1.** Social situation.

### 3. Results

#### 3.1. Air quality index

Based on data on July 26, 2021 at 09:00 local time shows that Surabaya is the city with the highest air quality index (AQI) of 107 which is categorized as unhealthy for sensitive groups. It shows the concentration of PM2.5 in Surabaya is three times by the WHO exposure recommendation (Figure 2) [2].

![Air quality index in Surabaya](aqi_situation.png)

**Figure 2.** Air quality index in Surabaya

One of the reasons for this situation is due to the industrial areas such as SAQI – Benowo, RespoKare Mask – Kertajaya, SAQI – Keputih, and Surabaya Tandes with AQI of 179, 173, 162, and 107, respectively. Currently, until June 2021, air pollution is estimated to have caused 1,900 deaths and loss regional income of USD 490 million [2]. Meanwhile, based on Air Pollution Standards Index (ISPU) issued by the Ministry of Environment as of June 28, 2021 at 08:00 Indonesian Western Time, it shows that the 24-hour ISPU value for the Surabaya is 81 and is categorized as medium [8].

#### 3.2. Energy situation in Indonesia

In 2018, total production of primary energy which consists of oil, natural gas, coal, and renewable energy reached 411.6 MTOE. Meanwhile, the total final energy consumption (without traditional biomass) was around 114 MTOE including transportation sector (40%), industrial (36%), household (16%), commercial (6%), and other sectors (2%) [9].
3.2.1. **Petroleum.** Over the last 10 years, oil production has decreased from 346 million barrels in 2009 to 283 million barrels in 2018. Due to the fact that, Indonesia imports petroleum to meet the needs of oil refineries that are dependent on imports nearly 35%. On the other side, the demand for fuel including domestic biodiesel in 2018 reached 465.7 million barrels/year. To meet this demand, Indonesia produces fuel from domestic refineries an average of 278.1 million barrels and imports an average of 165.4 million barrels [9].

3.2.2. **Coal.** In 2018, Coal production escalated to 557 million tons and 63% or 357 million of the total production was exported. On the other hand, domestic coal consumption reached 115 million tons and was lower than the target of 121 million tons [9].

3.3. **Power plants capacity in Indonesia**

Based on data on June 2020, power plants capacity in Indonesia reached 70,964 MW and more than half (63%) were in Java, Bali and Nusa Tenggara. Those areas have 44.8 GW and are followed by Sumatra with a capacity of 14.7 GW. Until now, PLTU still dominates power plants in Indonesia by producing 35.22 GW which is equivalent to 50% of the total generating capacity [5]. The percentage of national installed capacity per type of generator (%) is shown in Figure 3. Furthermore, for the detail capacity for each generator in the year 2017, 2018 and 2019 is described in the Table 1. This paper also describes the number of power generation units in Indonesia in 2019 which can be seen in Table 2. Based in Table 2 Indonesia has 5,678 unit of power generation with PLTD (Diesel Fired Power Plant) contributed the most of power generation amount 4,973 units and starting provide renewable energy power plant such as solar, hydro, geothermal, wind, and biomass. Eventhough machine has dominate for providing energy, renewable energy introduce and keep growth in Indonesia.

![Figure 3. Percentage of national installed capacity for each generator (%). Sources: Electricity statistics 2019 [10]](image-url)
Table 1. Power plants capacity (MW).

| Type of Generator                      | PLN Installed Capacity by Type of Generator (MW) |
|----------------------------------------|--------------------------------------------------|
|                                        | 2017 | 2018 | 2019 |
| Hydro Power Plant                      | 4,853| 5,436| 5,690|
| Steam Fired Power Plant                | 29,129| 32,226| 34,814|
| Gas Fired Power Plant                  | 3,674| 5,467| 5,639|
| Combined Cycle Power Plant             | 11,597| 11,249| 11,525|
| Geothermal Power Plant                 | 1,503| 1,986| 1,986|
| Diesel Fired Power Plant               | 6,919| 6,384| 4,878|
| Gas Engine Power Plant                 | 299| 886| 1,745|
| Micro Hydro Power Plant                | 137| 152| 170|
| Solar Power Plant                      | 11| 14| 18|
| Other Generator                        | 265| 146| 143|
| Power Installed Capacity               | 58,387| 63,947| 66,608|

Sources: Statistics Indonesia [11]

Table 2. Number of power generation units in Indonesia in 2019.

| Type of Generator                      | Unit |
|----------------------------------------|------|
| PLTU (Steam Fired Power Plant)          | 90   |
| PLTU MT (Mine Mouth Power Plant)        | 10   |
| PLTU-M/G (Waste Power Plant)            | 13   |
| PLTG (Gas Fired Power Plant)            | 71   |
| PLTGU (Combined Cycle Power Plant)      | 70   |
| PLTMG (Gas Engine Power Plant)          | 140  |
| PLTD (Diesel Fired Power Plant)         | 4,973|
| PLTA (Hydro Power Plant)                | 134  |
| PLTM (Mini Hydro Power Plant)           | 78   |
| PLTMH (Micro Hydro Power Plant)         | 41   |
| PLTB (Wind Power Plant)                 | 4    |
| PLTBm (Biomass Power Plant)             | 1    |
| PLTP (Geothermal Power Plant)           | 19   |
| PLTS (Solar Power Plant)                | 118  |
| Total                                  | 5,678|

Sources: Electricity statistics 2019

3.4. Discussion

Industrial process is one of biggest contributors in enhancing air pollutions in Surabaya since it contains various elements of GHG emissions such as carbon and nitrogen that bring detrimental impact on environment and health. Carbon emissions can lead to climate change and rising temperatures, it derived from vehicle emissions and industrial process. Moreover, it raises the number of mortality, respiratory morbidity, and infectious diseases due to heat waves from high temperatures [12]. In addition, the carbon dioxide in the atmosphere will affect the climate for hundreds or even thousands years and human health conditions for the long-term accumulation process. These conditions make it difficult for human health to immediately respond to climate change [12].

Beside the carbon emissions, in Surabaya, air contamination also contains nitrogen emissions. Consider to the WHO, nitrogen emissions containing nitrogen dioxide (NO₂) lead direct effects on health such as pediatric asthma. High concentrations of NO₂ prolong and worsen common viral infections and cause severe lung damage [13]. Furthermore, nitrogen emissions containing O₃ (ozone) also bring out a serious impact on health through inhalation and causes asthma and chronic respiratory
disease. Based on a review of the health risks of O₃ by the WHO showed an increase in mortality and respiratory morbidity as a result of the adverse impact on lung function. On the other hand, PM exposure, particularly those <2.5 (PM2.5) in diameter, causes respiratory and cardiovascular morbidity [13].

In addition, nitrogen emissions also bring indirect effect on health which is potential for skin cancer as a result of increased UV radiation due to the destruction of the stratospheric ozone layer. Research by Ravishankara et al. estimates that the ozone layer has decreased about 6% compare to before industrialization. Other health effects caused by increased nitrogen are increased production of powdered allergens, malaria, cholera, and schistosomiasis [13]. Besides being harmful to health, nitrogen emissions are also harmful to the environment. The threat of drought is one of the negative effects of increasing concentrations of ammonia (NH₃). Meanwhile, nitrogen oxides (NOₓ) bring detrimental affect on natural vegetation growth and agricultural which lead to diminishing harvest. In addition, ozone (O₃) affects loss of harvest and decreased seed production [13].

In Surabaya, escalation of GHG emissions bring out industries to create a new strategy which more aware on public health and environment. Hanmin Dong et al. present that companies or industries prioritize using adaptive measures rather than mitigation policies in responding climate change. Surabaya which is classified as a high level industrialization area can develop sophisticated technology through improving industrial structures as an adaptive step [12]. Furthermore, stages to encourage emission mitigation can also be considered to prevent environmental damage and health problems as a result of re-industrialization [12].

Government and industry should look for strategies for diminishing GHG emissions in Surabaya regarding to their impact (including carbon and nitrogen) caused by industrial processes. Ministry of Environment and Forestry deliver the Long-term Strategy on Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050) to UNCF targets the achievement of net-zero emissions by 2060. According to the Minister of Environment and Forestry, public has demanded green development so that climate change and carbon neutrality are essential subjects that are being managed in the national framework [14]. Therefore, implement a green economy is greatest step to do.

Green economy (GE) is based on the understanding that the economy depends on the natural environment and on the co-existence of humans and nature [15]. The concept of green economy in terms of sustainable urban development is a dynamic interaction between economic, social, and environmental [16]. Green economy can be supported by environmental or energy policies and requires innovation and investment. The concept of green economy is very attractive to government and business because it aims to provide simultaneous solutions to unemployment and environmental problems with new green industries and tools to reduce environmental damage [17]. Karl Burkart defines GE based on six main sectors, which are renewable energy, green buildings, sustainable transport, water management, waste management, and land management [18].

| Type of Energy     | Potency        |
|--------------------|----------------|
| Hydropower         | 94.3 GW        |
| Geothermal         | 28.5 GW        |
| Bioenergy          | PLT Bio : 32.6 GW |
| Solar              | Biofuel : 200 thousand Bph |
| Wind               | 60.6 GW        |
| Ocean Energy       | 17.9 GW        |

Sources: Director general of new renewable energy and energy conservation 2018

The implementation of GE is closely related to the circular economy and bioeconomy in determining the policies [19]. One of the policies is to utilize the potential of new and renewable energy. According to Government Regulation (PP) No. 79 of 2014 concerning National Energy
Policy, the target of new and renewable energy (NRE) is at least 23% in 2025 and 31% in 2050. It reveals that Indonesia has a large enough potential for renewable energy to achieve the primary energy target (Table 3). The total potential of NRE equivalent to 442 GW is currently used for power generation. Meanwhile, biofuels and biogas of 200 thousand Bph are utilized for the industrial, transportation, household, and commercial sectors [9].

Utilization of the potential of NRE has also been supported by several government regulations, such as:
- Presidential Decree No. 4 of 2016 (Article 14) concerning the Acceleration of Electricity Infrastructure
- Presidential Decree No. 66 of 2018 concerning the Second Amendment to Presidential Decree No. 61 of 2015 concerning the Collection and Use of Palm Oil Plantation Funds
- Regulation of the Minister of Finance No.177/PMK.011/2007 concerning Exemption of Import Duty on Imported Goods for Upstream Oil, Gas, and Geothermal Business Activities
- Regulation of the Minister of Finance No.03/PMK.011/2012 concerning Procedures for Management and Accountability of Geothermal Fund Facilities
- Regulation of Minister of Energy and Mineral Resources No. 49 of 2017 is a refinement of the Minister of Energy and Mineral Resources No. 10 of 2017 concerning the Principles of the Electricity Sale and Purchase Agreement
- Regulation of the Minister of Energy and Mineral Resources No. 50 of 2017 is a revision of the Minister of Energy and Mineral Resources No. 12 of 2017 concerning Utilization of Renewable Energy Sources for the Provision of Electricity
- Regulation of Minister of Energy and Mineral Resources No. 49 of 2018 concerning the Use of Rooftop Solar Power Generation Systems by Consumers of PT Perusahaan Listrik Negara (PLN)

Pertaining to the policies, it is possible to implement green economy in industrial sector in Indonesia. As previously mentioned, Surabaya contribute in enhancing GHG emissions through air pollution due to factory processes that almost existing manufacture operate boiler. For reducing it, company should replace of boiler utilization to electricity-based machines produced by NRE.

In 2018, Power plant capacity reached 64.5 GW and growth of 3% compared to 2017. This capacity comes from fossil energy, especially coal (50%), natural gas (29%), oil (7%) and renewable energy (14%) (see Figure 4) [9]. There are several energy policies. First, strategic plan of the ministry of industry. Second, estimated energy demand for the industrial sector which is divided into two types, special industries and other industries. Specific industries consist of industries consume plentiful of energy such as the fertilizer, cement, and ceramic [9].

![Diagram of Energy Sources](image)

Source: *Handbook of Energy & Economic Statistics of Indonesia (HEESI) 2018*

**Figure 4.** Installed capacity NRE power plants per type of energy 2018

Regarding energy demand projection from the Ministry of Energy and Mineral Resources, there are six industrial sub-sectors that consume numerous energy, such as cement, metal, food and beverage, fertilizer, ceramics and paper industries with total energy demand virtually 87% that almost of them are located in Surabaya [9]. Surabaya has various industrial sub-sectors, from the manufacturing industry to the home furnishing industry. Moreover, government also projects the supply of NRE,
especially the use of biomass as a substitute for coal. In 2050, the supply of NRE nearly 275.2 MTOE (BaU), 264 MTOE (PB), and 477 MTOE (RK) [9].

Solar energy power plant has a large-scale generator called Utility Scale Solar Energy (USSE) and has a lifespan of 25-40 years [20]. Meanwhile, hydropower power plant is still the largest source of NRE. Beside as renewable and reliable low-carbon electricity, it leads benefits such as keep off flood/drought and water supply control [20]. In addition, NRE is related to supply chain performance and dynamic capabilities that simultaneously and partially affect business performance [21].

Employing green economy through utilization of electricity-based machines in Surabaya can be realized regarding NRE potential, NRE projected demand, and NRE projected supply. This alternative can be challenging due to it require huge budget and increase electricity consumption. To minimize this drawback, switching of boiler machines to electricity-based machines can be implemented gradually, such as utilization of solar and wind energy. As a consequence, GHG emissions, especially in Surabaya are diminished and NRE power plants in East Java are sufficient to supply electricity because they have large power plants such as hydropower in the Sutami Karangkates and steam fires power plant of Paiton. Table 4 describes the number of power generation in East Java in 2019 with total 150 units. Hydro power plant (as a mention before in Sutami Karangkates) operates 28 units for supply energy in East Java. Other renewable power generation operated by solar, micro, and gas engine.

| Type of Generator | Unit |
|-------------------|------|
| PLTU (Steam Fired Power Plant) | 7 |
| PLTU MT (Mine Mouth Power Plant) | - |
| PLTU-M/G (Waste Power Plant) | 4 |
| PLTG (Gas Fired Power Plant) | 7 |
| PLTGU (Combined Cycle Power Plant) | 17 |
| PLTMG (Gas Engine Power Plant) | 3 |
| PLTD (Diesel Fired Power Plant) | 89 |
| PLTA (Hydro Power Plant) | 28 |
| PLTM (Mini Hydro Power Plant) | - |
| PLTMH (Micro Hydro Power Plant) | 2 |
| PLTB (Wind Power Plant) | - |
| PLTbm (Biomass Power Plant) | - |
| PLTP (Geothermal Power Plant) | - |
| PLTS (Solar Power Plant) | 2 |
| Total | 150 |

Source: Electricity statistics 2019

4. Conclusion
The high level of AQI in Surabaya comes from existing industrial, such as SAQI – Benowo, RespoKare Mask – Kertajaya, SAQI – Keputih, and Surabaya Tandes. Surabaya has four major industrial areas, which are Surabaya Industrial Estate Rungkut (SIER) Rungkut, SIER Berbek, Sidoarjo Rangkah Industrial Estate (SiRIE) and Safe n Lock. The use of engine-based technology sourced from steam or diesel energy (boiler engine) is one source of air emissions. These emissions contain several pollutants of particulates (dust) or gases such as NO₂, CO, CO₂, and SO₂. Therefore, to minimize air pollution, it can be done by replacing electricity-based machines from renewable energy. This change is supported by the level of energy production in Indonesia where the production of fuel including biodiesel averaged 278.1 million barrels and coal amounted to 557 million tons in 2018. In addition, the power generation capacity of 70,964 MW also supports the implementation and dominated by steam fires power plant (PLTU) of 35.22 GW.
This alternative strategy is one way to reduce the impact of air emissions on humans and environment. The impact of air contaminations for humans is notable, such as causing pediatric asthma, prolonging and exacerbating viral infections, causing severe damage to the lungs, causing inhalation, potentially causing skin cancer, and increasing the production of allergen powders, malaria, cholera, and schistosomiasis. However, impacts on the environment include climate change and enhancing temperatures, depletion of the stratospheric ozone layer due to increased UV radiation, and the threat of drought. Therefore, the government should start employing the concept of a green economy in the industrial sector through the replacement of electric machines. This is in line with the government's target of achieving net-zero emissions. Moreover, the application of the GE concept is also supported by the number of existing NRE power plants, especially in the East Java with the Paiton Steam Fires Power Plant and Sutami Hydro Power Plant.

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