4-Bioenergy as an

by Ps 4-janter

SEMARAK ILMU
PUBLISHING

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Bioenergy as an Alternative Energy Source: Progress and Development to Meet the Energy Mix in Indonesia

Janter Pangaduan Simanjuntak[1,*], Khaled Ali Al-attab[2], Eka Daryanto[1], Bisrul Hapis Tambunan[1], Eswanto[1]

[1] Mechanical Engineering Department, Universitas Negeri Medan, Medan 20221, North Sumatera, Indonesia
[2] School of Mechanical Engineering, Universiti Sains Malaysia,14300 Nibong Tebal, Penang, Malaysia

ARTICLE INFO

Article history:
Received 17 March 2022
Received in revised form 21 May 2022
Accepted 30 May 2022
Available online 28 June 2022

Keywords:
Solid biomass; biodiesel; bioethanol; energy mix in Indonesia; gasification

ABSTRACT

Government policies in Indonesia have been pushing in the past decade towards 100% electrification target by end of 2020. However, many of the new energy policies are reused from previous policies designed for different objectives causing overlap in policies between the central and local governments. Local distributed generation are not fully controlled by local stakeholders and community, and with the lack of long-term planning, continuous government incentives and support, they are bound to fail due to the lack of maintenance. The use of solid biomass for household has decreased significantly due to the government support for LPG stoves that overtaken other government projects supporting biomass. Small-scale biomass research is showing good progress towards the implementation of novel methods for biomass utilization. However, majority of the medium and large-scale projects are still relying on old technologies such as direct biomass combustion in boilers rather than the more environment friendly gasification technology. Another major biomass contribution to national energy mix is through liquid biofuels. This work summarizes the current and prospective energy mix in Indonesia and the main conventional and non-conventional energy sources and their environmental concerns. This work also gathers the latest local biomass research and biomass power plant projects.

1. Introduction

The enrolment of Industrial Revolution (IR) 4.0 is a key milestone to the economy of Indonesia. However, as a developing country with large population, this poses a significant challenge with high technological equipment to support this development. The shift to IR 4.0 is expected to have a considerable influence on energy consumption which in turn has a direct effect on energy policy and sustainable energy goals [1]. A roadmap to IR 4.0 in Indonesia to achieve sustainable industry was proposed by Hidayatno *et al.,* [2] discussing the role of the different ministries in the government in conjunction with the private sector, industry and society. The negative effect of IR 4.0 on environment in terms of pollution and the increased demand for energy can be driven towards

* *Corresponding author.*
E-mail address: janterps@unimed.ac.id

https://doi.org/10.37934/arfmts.97.1.85104

increasing the industrial productivity to develop new technologies to enhance energy efficiency and to increase the renewable energy production share. Despite having a significant effect on energy sustainability, industrial sector comes second in terms of energy consumption as reported by the Indonesian Energy Outlook (IEO) [3]. The report stated that around 114 MTOE was consumed in the year 2018 (excluding traditional biomass), with highest consumption of 40% by the transportation sector, followed by industrial sector (36%), household (16%) and commercial sector (6%). The Indonesian Yearbook Statistics showed that the total number of registered motor vehicles including passenger cars, buses, trucks and motorcycles exceeded 146 million by end of the year 2018 [4]. A short-term strategic plan (2010-2030) was proposed by Deendarlianto *et al.,* [5] to reduce the energy consumption and environmental impact of the transportation sector in Indonesia. The proposal investigated several scenarios that implemented different options such as 20 years' vehicle retirement program, natural gas (NG) fuelled public transportation, hybrid vehicles and the adoption of different types of biofuels. Early retirement of vehicles below 20 years was proposed as the most significant factor for short-term along with the utilization of biofuels in new vehicles and NG in public transportation. Another statistical investigation limited the retirement of vehicles to 15 years and predicted the market to hybrid cars in Indonesia for the period 2018-2028 [6]. Results showed that the market for hybrid cars depended entirely on the competitiveness of the hybrid cars prices compared to the conventional ones. The statistical sample showed that around 32% of the people in the sample are willing to purchase hybrid cars if the prices are competitive. Jayed *et al.,* [7] investigated the possibility of the wide adoption of biofuel-flexible engines that can utilize biodiesel in Malaysia and Indonesia as the largest producing countries of palm oil. The study concluded that if biodiesel is adopted in commercial scale transportation to replace fossil diesel, then the production of biodiesel from palm oil will be economically feasible. Electrical vehicle (EV) is another widely investigated alternative to reduce the impact of transportation sector on energy sustainability. Indonesian government policy also indicates the shift towards this option as stated by the President Regulation No. 55/2019 concerning the acceleration of the battery–based electric motor vehicle program for transportation. Also, the President Regulation No. 73/2019 which sets the amounts of exhaust emissions and fuel consumption of the different vehicle categories [8]. One of the widely investigated potential benefits of EV is only to consume electricity but also to support the national electrical grid is known as the vehicle-to-grid (V2G) program. Several studies investigated the V2G potential to reduce the fluctuation of load in the national electrical grid in Indonesia and also to enhance the quality of the electrical supply in terms of the frequency fluctuation. The studies showed the potential for the parked EVs by motivating the participants through incentives from the service providers and a suitable government policy [9-11].

2. Energy Policy in Indonesia

2.1 Current Energy

The importance of energy access is acknowledged in the Indonesian energy low number: 30/2007 (Article 3, point f). The aim is to improve the accessibility to energy for the Low-income bracket and remote areas residents by providing assistance to increase the availability of energy and building energy infrastructures [12]. The residential electrification has reached 98.3% in March 2019 [13] exceeding the previous target of 97.5%, and the plan is to reach 100% electrification by end of 2020. As for the electrical load distribution in the year 2018, highest share of 42% was consumed by household, followed by 33% for industry, 25% for commercial use and below 1% for the transportation sector mainly by electrical commuter trains as shown in Figure 1 [3].

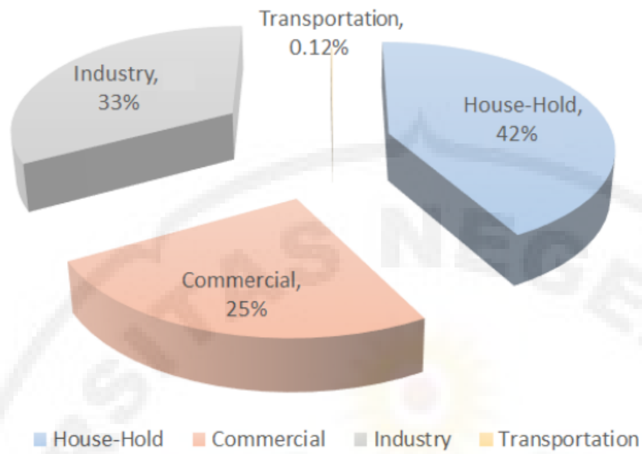

Fig. 1. Electrical load distribution on the different sectors in the year 2018 [3]

Erahman *et al.,* [14] evaluated the energy security index (ESI) in Indonesia based on energy availability, affordability, accessibility, acceptability and efficiency. The study found a steady annual elevation in ESI averaging about 2.7%. As the energy availability is a part of ESI, the rate of residential electrification has played a significant role, averaging an increment of about 5% per year during the studied period 2008-2013. This elevation rate reduced to about 4.4% per year up to the year 2017 reaching a national electrification of 95.35%, but the annual increment is expected to reduce to about 1% until the full national electrification target is achieved. One critical issue for fast spread of electrification in off-grid rural areas is the use of micro-grids or local distributed generation. On one hand, it can be achieved with minimal infrastructure and competitive cost for the short-term. On the other hand, it would have low chance of success if the purpose is to increase the number of installations for political campaign gains without a proper long-term planning with adequate government incentives for operation and maintenance. An important factor to avoid this scenario is the awareness of the local stakeholders and community, which can be aided by external players such as independent media, non-profit organization, academics, etc. [15]. This issue was further elaborated by Sato *et al.,* [16] regarding the existing micro hydro power plant in the off-grid rural areas. The power plant is handed over to the community and usually fail for the long-term due to the low operating and maintenance budget. The authors proposed the involvement of private companies to handle the power plants for the long-term with suitable government policy.

Reaching the set milestones of national electrification must go in parallel with the improvement of the peak-load generation. The industrial sector, especially the micro and small enterprises (MSEs), with no backup emergency generators suffer from the low reliability of electrical supply during the peak-load periods. It was estimated that the total financial losses caused by electricity blackouts in the MES sector in Indonesia can reach nearly USD 5 million annually [17]. Although, the economic status is heavily influenced by the ESI, there is no official definition or indexing of the energy poverty in Indonesia, and the common consent is that the energy poverty can be avoided by providing electricity and clean energy to households. The guideline provided by the International Energy Agency (IEA) limits the spend on energy to 10% of total income to be considered as energy-poor [18]. According to Sambodo *et al.,* [19], the multidimensional poverty index (MPI) accounts for three main factors namely: health, living standard and education. The study considered the IEA standard limit with electricity minimum consumption of 100 kWh/person/year or 32.4 kWh/household/month to be considered as energy-poor. Based on these international standards, the study concluded that about 53% of household in Indonesia are energy-poor and the transportation section consumed the highest share of energy spending. It also found that the non-energy-poor households spend more on the non-food items compared to food-items unlike the energy-poor households. Another factor that affected the Indonesian economy considerably is the reliability of the electricity supply. Electricity demand forecasting through 2030 was investigated using load curve modelling by McNeil *et al.,* [20]. The study predicted an increase of 205% in electricity demand in the period 2010-2030 reaching up to 77.3 GW. Peak loads were predicted mainly by air conditioning and other appliances; however, the use of smart energy management and efficiency residential appliances could drop the peak load by 26 GW. Residential energy efficiency targets can be achieved through the movement towards the smart-city scheme planned by the Indonesian government. The guidelines for Smart City Master Plan were published by the Ministry of Communication and Information Technology [21]. Statistical data were gathered to investigate the status of six major cities in Indonesia as the main candidate for the smart city target [22].

2.2 Energy Resources

Energy is essential to drive all the developing sectors, but the problem arises from the fact that the main source of energy in Indonesia is still currently dominated by fossil fuels [3]. However, as the Indonesian economy is heavily dependent on fossil fuels, abandoning the use of fossil fuels entirely is not an option. Alternative carbon-neutral energy sources mainly nuclear and renewable are currently considered to cover a portion of the energy requirements. The decentralized political nature of Indonesia with the governance at a multilevel necessitates that trust build-up passes through the sub-national level in horizontal manner and then it goes up to the national level. Therefore, controversial energy sources such as nuclear needs to be heavily promoted to the local governments by the National Nuclear Energy Agency of Indonesia (BATAN). First public survey on nuclear power was conducted in 2010 by BATAN and yielded around 60% public acceptance, while the yield dropped to 49.5% in the second survey in 2011 after the Fukushima nuclear disaster [23].

According to the national statistics in 2019, energy mix in Indonesia for electrical power production comes mainly from coal (50%), followed by natural gas (29%) and crude oil (7%) as shown in Figure 2 [3]. The contribution to the national grid from renewable energy is mainly by large hydro power plants contributing around 7%, while other renewable resources contributes around 7% despite the government support and subsidies. However, for the general energy mix for all sectors, oil consumption showed significantly higher demand reaching 32% of total energy demand on par with coal since it presents the main fuel for the transportation sector. Total gas consumption was 29% in 2018 which included natural gas and also liquefied petroleum gas (LPG), while total renewable energy contribution (including hydro) was quite limited of 9% only. The fast economic growth in Indonesia in the past three decades elevated urbanization and energy consumption rates, which resulted in steady increment coal share in the energy mix [24]. However, with sharp drop on coal prices, natural gas presents a good candidate in Indonesia to preach the gap for the medium-term from the economy and environment perspectives [25]. However, with the increased local demand for NG and the slow development in the infrastructure of NG exploration and production, Indonesia is moving towards being a net importer in the near future [26]. Coalbed methane (CBM) reserve was estimated to be 453 trillion cubic feet with huge potential to reduce the current energy mix in Indonesia. However, with the current under-investment and lack of exploration, CBM is not expected to affect the short-term energy mix strategies [27].

The availability of renewable energy resources in Indonesia in abundance opens the possibilities and future scenarios for speculation. However, the implementation of renewable energy (other than large hydro) is still lacking behind where the contribution was about 3% back in 2011 [3] and increased by only 4% in the current decade despite the efforts and planned strategies by the Indonesian government.

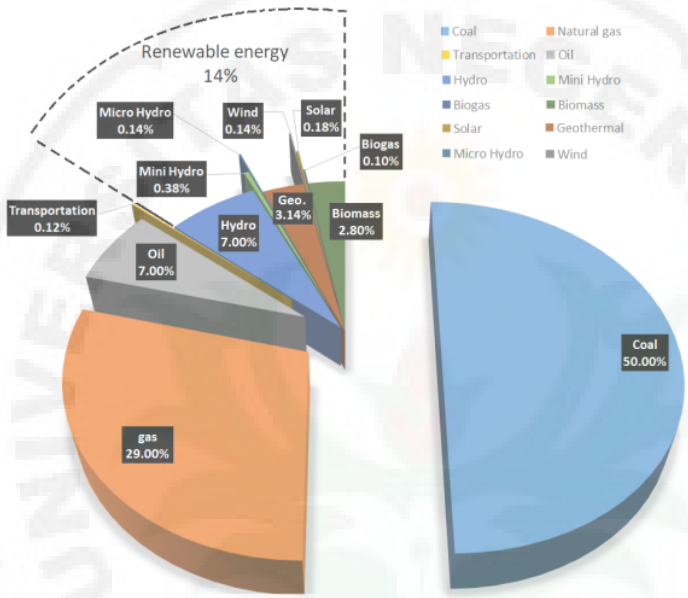

Fig. 2. The installed capacity of electricity energy from renewable sources in 2018 [3]

Predictions by IEO [3] for the general energy mix for all sectors were simulated in three different scenarios: Low Carbon (RK), Sustainable Development (PB) and Business as Usual (BaU). The predictions were based on fixed population growth rate of 0.7%, and the results for the years 2025 and 2050 for the three scenarios are summarised in Figure 3 [3]. For the BaU model, coal consumption is expected to be maintained at the same current value of 32%, while renewable energy is expected to play more significant role with the current government policy to move towards low carbon footprint, reaching 29% by 2050. On the other hand, RK scenario presents the highest dedication towards green policy reaching up to 58% contribution from renewable energy by 2050 while reducing coal down to 22%. All scenarios predicted a significant drop in oil consumption with the current government plans to move towards electrical vehicles, biodiesel, bioethanol and gas fuels for the transportation sector.

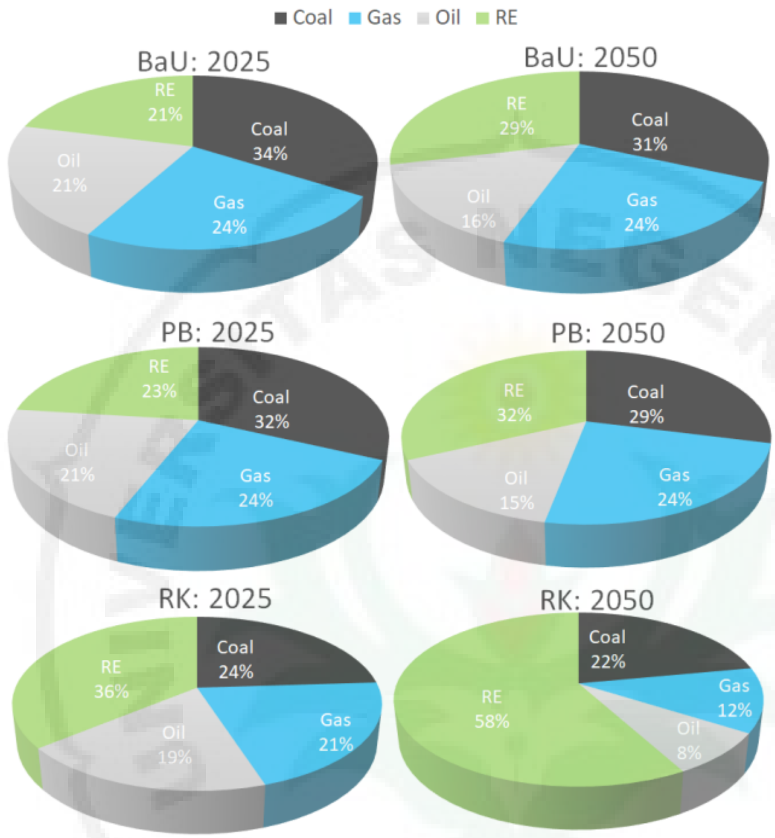

Fig. 3. Indonesia energy mix target by 2025 and 2050 for BaU, PB and RK scenarios [3]

RK scenario presents the highest renewable energy share of 58% in the year 2050. However, for the long-term energy mix planning, depletion and drop in production rates of the main fossil supplies: coal, gas and oil has to be considered. New long-term government policies to prioritize renewable energy have to be established to maintaining national energy security and independence. The main issues facing the development of renewable energy resources in Indonesia are the government regulations, the environmental aspect, and infrastructure problems [25]. Lessons from the past failures have to be learned to avoid hindering the progress towards the renewable energy commitment in the future. The Aceh Green initiative (2007-2012) by key UN bodies and donors aimed at shifting the economy towards the "green-economy" principle. However, Swainson and Mahanty (2018) summarized the factors that led to the failure of this initiative as it focused on the end goals and ignored the necessary negotiations with the political structures. Despite the seemingly support of the green economy by the politicians, the current economy structure is based on conflicts and contests over power by various groups. Thus, clear analysis of the interests and goals of the different groups in the green economy structure with the necessary trade-offs are needed for the intervention to success [28].

2.3 Renewable Energy and Environmental Impact

The announced Intended Nationally Determined Contribution (INDC) of the Indonesian government indicated the commitment to greenhouse reduction up to 29% in alignment with the 2015 Paris Agreement. Continuing with the current fossil-based power generation, greenhouse emission is expected to increase by nearly threefold by 2030 [29]. Therefore, Handayani *et al.,* [30] investigated the possibility of expanding the power system to meet the electrification demands while still achieving the INDC target by 2030. The main factor was found to be the increment in the natural gas share in the energy mix while reducing coal, as 11-14% reduction in greenhouse emissions can be achieved. Other factors included the expansion of the renewable energy sources, mainly geothermal, hydro and biomass with smaller shares of photo voltaic (PV) and wind. Al Irsyad *et al.,* [31] investigated similar greenhouse emissions reduction target to the previous study with expansion in the existing power plans fuelled by coal, natural gas and oil. Expanding the capacity of the current power plants failed to reach the emission target by the year 2028. The study predicted higher contribution of wind energy especially the offshore due to the maturity of wind turbine technology lowering the technical risk and cost. This was followed by the large and micro scale hydro power plants, biomass and PV. Small scale vertical axis wind turbines have been getting more attention lately as they can operate efficiently in direct installation on rooftop along with PV as hybrid system [32]. Some of the challenges facing the contribution of renewable energy to the national electrification are the high fossil fuel subsidies, monopolistic nature of electricity-policy dominated by the state electricity company or Perusahaan Listrik Negara (PLN) and the absence of long-term policies that can involve privet electricity generation such as feed-in-tariffs [33]. Energy policy reformulation is needed for the long-term to include the private sector as a major player in the national electrification in order to meet the INDC [33].

So far, hydro power presents the main renewable energy source in Indonesia with the geographical advantage within the tropical rain belt resulting in high number of rivers. This is further aided by the higher power efficiency compared to other renewable resources in the range of 60-90% [34]. Mini and micro hydro power are promising candidates for the prospective landscape of renewable resources in Indonesia due to the wide spread of small and medium rivers with low payback period compared to the other renewables [35]. Another geographical advantage is the unique location above the belt of fire providing huge potential of medium and high temperature geothermal power generation of nearly 29GWwhich was estimated to be about 40% of the global potential [36]. Wide range of mapping and prediction techniques for the active sites have been investigated [37]. The short-term plan set by the government is to reach about 9.5 GW generation capacity by the year 2025, but the target was eventually revaluated down to 7 GW [38]. Majority of the installed geothermal power plants operates on single-flash design while only two plants operates on dry-steam design [38].

Solar energy can be utilized as direct electricity using PV panels or as heat source through solar collectors [39] or combined heat and power using water-cooled PVT systems [40]. PV panels saw significant elevation in the number of installations in the rural areas since 2015. However, most of the installations was supported by foreign investments, which constrains the local investments and increases the economic risk for the long-term [41]. Burke *et al.,* [42] discussed the energy policy constrains in Indonesia facing the small and medium solar and wind investments when connected directly to the grid with frequent changes in the regulations since 2013 especially for PV.

3. Bioenergy in Indonesia

3.1 Environmental Impact

Biomass and biofuels are usually perceived by the public as polluting and non-environment-friendly fuels. The main sources for the environmental concern related to biomass are the forestry management, the use of biomass in household for cooking and waste management. The concept of waste-to-energy was reviewed, and it was shown to be a key factor towards low-carbon policy [43]. As for the first source, pollution and greenhouse emission concerns are mainly related to the policies of deforestation, forest and peatland degradation. The land use change and peat fire contributed nearly 60% of the annual emissions in Indonesia in 2014 [44]. The first phase of National Action Plan for Greenhouse Gas Emissions Reductions (2010-2014) was implemented as part of the preparations for the INDC commitment [45]. However, many flaws in the design of the actions prevented the achievement of the target greenhouse emission in the forestry sector. Many of the actions were reused from previous policies designed for different objectives and not aimed directly at the reduction of emissions [46]. The design of the actions should include restricted control of deforestation, incentives and supported projects for forest rehabilitation and carbon conversion [47]. Mangroves forests with its high carbon density has high potential of rehabilitation reaching up to 3 folds higher greenhouse reduction compared to other forestry resources [48]. Illegal logging and illegal land clearing with open fire were identified as the main causes of forest degradation and increased the chance for forest fires [49]. Edwards *et al.,* [50] tracked the forestry fire causes in dry seasons in Indonesia to be partially affected by decentralization of the districts and the economic growth in those districts. Statistics showed that villages in more remote and underdeveloped areas where fire is practiced for agriculture were more prone to be affected by forest fires. Oil palm plantation is a major player in the environmental aspects where concerns have been raised as the expansion in plantation cased around 20% reduction in rainforest area since the year 2000 [51]. Another issue is the life cycle greenhouse footprint from palm oil production. Although, the total contribution of palm oil is less than 7% of the total footprint, the contribution ranges from 1% up to 52% depending on the region, where some places in Indonesia are overly used for oil palm plantation [52]. The negative effect of palm oil production on greenhouse footprint can be significantly reduced by limiting the plantation expansion to the non-forest areas and by limiting methane release to atmosphere by improving the production process [52]. Recent research on CO_2 and methane capture techniques have shown significant advancement through adsorption at wide range of temperatures [53].

As for the second source of environmental concern, nearly 89% of population used kerosene with other fuels for the household cooking [54], while biomass was used by nearly 50% of the population by the year 2004 [55]. Therefore, government initiative was started in the end of 2007 and through 2008 to promote the use of LPG for cooking through subsidies and the distribution of free LPG packages containing stove and 3kg LPG container. This campaign aimed at reducing the energy poverty also to reduce the health risks from smoke and CO emissions from the improper combustion of biomass [55]. Investigating the public respond to this campaign showed that to those who refused to switch from biomass to LPG, the later was viewed as a hazardous fuel, and also, they preferred the traditional cooking style and taste. In general, the campaign has shown a good success with an elevation in LPG use from 10.5% up to 47%, with reduction in kerosene use from 36% down to 9% [57]. The use of LPG with modern stoves not only improves the wellbeing of the household as a cleaner fuel, but, it can be also utilized as a mid-step to switching to green fuels such as biogas in the medium and long terms [58]. For the short-term solution for utilizing biogas, studies showed that biogas produced in farm households is plausible for the short terms and showed a good respond from the surveyed farmers. However, the production complication and the resistance to switch from the traditional cooking with firewood were the main obstacles [59-61]. For the medium-term, biogas digesters in distributed generation facilities could be utilized in junction with the available LPG infrastructure for household cooking were LPG can be used as backup supply in case of supply shortage [62]. However, for the long-term commitment to the restricted greenhouse emission policy, biogas production from sewage-sludge central treatment could be incorporated to central gas distribution in different districts [63].

The management and disposal of municipal solid waste (MSW) is another environmental concern. However, the high plastic content (up to 14%) in MSW presents the major concern were majority of the plastic ends up in the sea causing serious pollution of the marine environment [64].

3.2 Bioenergy Policy

Biomass potential in Indonesia is very large with abundance of variety of fuel resources that can be utilized as a national energy supply in the future. However, biomass energy is not fully utilized with less than 3% contribution to the national energy mix in the year 2018 [3]. The early attempt of the Indonesian government to set the goal for biofuel production (President Regulation No. 5/2006) was ambitious with a target of 2% biofuel contribution to the national energy by 2010 and 5% by 2025 [8]. However, many shortcomings slowed down the shift to biofuels including the overlap in policies between the central and local governments, weak government support of biofuel production with the cancelation of the early subsidies and insufficient R&D and infrastructure for production and utilization in transport and power sectors [65]. The largest biomass resource in Indonesia is the forest residues were about 68% of the land area is covered by forest. The economic evaluation showed that converting forest residues into pellets will increase its value in market up to 5.6 U$D/ton where it can be used directly in combustors, boilers of gasifiers [66]. Few decades ago, biomass from forestry and crop wastes presented the main fuel for household energy supply for cooking and water heating which had negative impacts in terms of safety and health concerns. However, low prices of kerosene and LPG dropped the share of biomass energy usage for household in the last decade significantly. Programs such as biomass cooking stove initiated by the government [67] to continue the trend of biomass using but with more environment friendly approach was not able to compete with the new cleaner fuels. Another point of view to reduce greenhouse emission is by increasing the "*in-use wood-based carbon stocks*" from forestry which is around 30% in Indonesia. This is done by delaying the release of carbon to atmosphere through the production of long-lasting wood products that can be used by community such is building materials [68].

Oil palm became the largest agriculture sector with rapid growth in large-scale plantation which triggers the environmental concerns as it resulted in many social and environment impacts. The conflict in state and non-state policies of plantation and production certification has led to the introduction of Indonesian Sustainable Palm Oil (ISPO) policy national certification for all Indonesian oil palm plantation companies [69]. The challenges and legalities facing the independent palm oil plantation and production smallholders to comply with the ISPO requirement were discussed by Schoneveld *et al.,* [70]. The use of palm oil for bioenergy production is still debatable. The use of new land for oil palm plantation has to be controlled to avoid deforestation as well as the disturbance of food security and urbanization. Many researches evaluated the positive and negative effects of the expansion of oil palm plantation on environment, society, and economy of Indonesia. Papilo et al, [71] evaluated the Sustainability Index Assessment (SIA) of biofuel production from palm oil based on social, environmental, and economic aspects. The average SIA score was 35% with unstainable (16%) social aspects in terms of job and income security as well as the access to modern energy services. The economic aspects showed slightly better sustainability score of 38% which include the availability and diversity of energy as well as the needed logistics and infrastructure for bioenergy development. Lastly, the highest score was 51% for the environmental aspects with moderate sustainability in terms of the greenhouse footprint life cycle assessment and waste management [71].

For power generation using solid biomass, several obstacles need to be overcome including high investment and operational costs, short lifespan of equipment, difficulties in controlling emission and particulate matter (PM) pollution, and high cost of raw biomass pre-treatment and transport [25]. Biomass utilization can be feasible for small and medium scale distributed generation near fuel sources such as rice and oil mills [72,73]. Oil palm mills deal with fresh fruit bunch to produce oil, however, around half of the mass ends up as waste in the form of kernel shells and empty fruit bunches. These important types of biomass can be converted into gaseous fuel known as producer gas (PG) to run engine to provide the needed heat and power for the mill [74].

Liquid biofuels, on the other hand, can solve most of the issues associated with solid fuels with easier fuel handling and higher energy density. The National Biofuel Development Team (TimNas BBN) was established back in 2006 to set the road map for biofuel development in Indonesia [75], with a set target of 5% contribution to the national energy mix by 2025 [4]. One of the early bio-ethanol production facilities was established back in 1982 in Lampung using plant cassava waste as the raw material [76]. The policy of biofuel targets and blends with gasoline for transport sector have changed through the years, with the latest target (presidential regulation no. 12/2015) set to 10% by 2020 and 20% by 2025 of the total gasoline consumption. Another important source for bio-ethanol production is the sugarcane, where land use for sugarcane plantation has to increase from 0.47 Mha in 2015 up to 1.14 Mha in 2025 to achieve the production target [77]. The life cycle assessment of greenhouse emissions from bio-ethanol production process with cane molasses as the raw material resulted in 29 g of CO_2 eq. per MJ of ethanol, which presents a 67% emission reduction when compared to gasoline production process [78]. Sweet potato (Ipomoea batatas) is another important candidate for bio-ethanol production as well as essential food element for rural and suburb areas. Early commercialization of wide range of products including ethanol was established by the Toyota Bio Indonesia (TBI) project [79]. The production rate is currently in the range of sweet potato 8.2-22.6 t/ha but with improved cultivation technologies in can reach 30 t/ha and above. The high production capacity up to 6 m^3/ha bio-ethanol at activation rate of 30 t/ha with low production rate makes it more feasible compared to the commonly used cassava raw material [80]. Another raw material with high economic potential and high production yield of bio-ethanol through fermentation is sorghum plant [81]. Forestry residues and waste from timber industry are alternative resources for liquid biofuel production with large economic and environmental potential, but still not utilized [82].

The other main liquid biofuel for transport and power sectors is biodiesel. One of the main candidates for biodiesel production is Jatropha curcas which produces non-edible oil unlike the other edible resources which adds to the fuel vs food conflict [83]. It was shown that biodiesel production from J. curcas can be economically feasible and can compete with the fossil diesel if government subsidies are applied [84]. Another source for biodiesel production is the rubber seed which is considered as waste and not used by the farmers in Indonesia. A case study was investigated using mobile processing unit (MPU) to be mobilized between several villages during the season to maximize production capacity of biodiesel [84]. The results showed that smaller equipment to ensure the mobility can achieve profitable margin with return of investment exceeding 10% if used in the high rubber seed harvesting areas. However, palm oil is the main candidate for biodiesel production in Indonesia. Harahap *et al.,* investigated the economic feasibility of biodiesel production from crude palm oil (CPO) for several case studies. Using the oil palm waste residues to fuel boilers for co-generation to supply the required heat and power for the oil mills with biofertiliser as additional product was found to be more feasible compared to biogas production from the oil palm waste through anaerobic process [85].

3.3 Small-Scale Research Activities

Biomass fuel was the most utilized fuel in small scale application until few decades ago. The oldest and most common method to utilize solid biomass or convert it into liquid or gaseous fuels for small applications is through thermochemical processes at moderate to high reaction temperatures. Other conversion methods based on chemical reaction or bacterial fermentation were introduced recently but mostly aimed towards the medium and large-scale liquid or gaseous fuels commercial production with very limited utilization in small-scale application. The awareness of the modern and environment friendly thermochemical methods for biomass utilization is still very limited among the public, which raises the concerns on health and environmental issues especially in urban waste management [86]. Thermochemical two stage combustion using modern biomass stoves has been proven to be an efficient and environment friendly method for the small-scale and household utilization of agriculture wastes [87]. Biomass gasification is one of the early technologies that gained population in Indonesia for small-scale power production [88]. In gasification, biomass is converted into combustible gas known as producer gas using heat and reaction agent such as air, oxygen, steam or carbon dioxide. However, air gasification is still the most used method due to its simplicity and economic superiority despite having lower quality of the gas product [89].

The main downside of raw biomass fuel resources that prevent it from being utilized widely as replacement of the commonly used low-grade coal is the high moisture content and low energy density. This makes the transportation of raw biomass to be utilized for power generation in places other than their production origin not feasible. One of the common methods to upgrade biomass is by converting raw biomass into bio-pellets. A small-scale bio-pellet production facility using empty fruit bunches waste from palm oil mill has shown a good economic feasibility, which can compete with the biomass briquets, wood and coal selling prices in the local market in Indonesia [90]. It was shown experimentally that high quality wood pellets can increase the efficiency of gasification and the quality of the gas product considerably [91]. For low-quality raw biomass with high moisture content (above 50%) such as bagasse waste from sugar production industry, low temperature torrefaction (at 150°C) was found to be feasible with acceptable product quality that can be used efficiently for gasification or direct combustion [92].

Solid biomass material is commonly converted first into more useful liquid or gaseous form for more efficient utilization in heat and power application. Low grade biomass waste can be converted into liquid bio-oil through pyrolysis which is a thermochemical reaction at moderate temperatures in the absence of oxidizer [93]. A lab-scale fluidized bed pyrolysis reactor was tested with empty fruit bunches waste from palm oil industry, using nitrogen gas as the fluidization agent in the temperature range of 400-600°C [94]. Pyrolysis output yield of char, gas and bio-oil depended heavily on the operating temperature with higher oil yields at lower temperature. Bio-oil refining produced light-to-heavy oil range with heating value above 40 MJ/kg that can be used directly in internal combustion (IC) engine for power production. Other row materials such as bagasse waste were also tested for bio-oil production in a fixed bed pyrolysis reactor, and the addition of CaO and MgO catalysts have shown positive effect on improving the reaction rate [95]. The benefits on fuel quality when upgrading cocoa pod husk as one of the abundant agriculture wastes in Indonesia was tested experimentally using pelleting then carbonization processes [96]. Other than the thermochemical conversion process, using bacterial agents in a fermentation process has been getting more attention to convert organic-rich waste materials into gaseous fuels such as bio-hydrogen [97] and bio-methane [98-100].

Figure 4 shows the biomass research and development projects at the mechanical engineering, Universitas Negeri Medan. Some of the tested agricultural residues in gasifiers and stoves shown in Figure 4 include (a) Candlenut shells, (b) Peat soils, (c) Sawdust, and (d) Coconut shells. Figure 4e shows the gasification with sawdust as feedstock with a novel internally circulating fluidized bed which can achieve stable gas production with heating value of about 7 MJ/m^3 [101, 102]. Fixed–bed type gasifier was also tested using candlenut shell and coconut shell which can be used to produce flammable gas as shown in Figure 4f [103]. The use of producer gas for IC engines in Indonesia has a promising future for power generation where engines can operate with a minimum heating value of 3 MJ/m^3 [104]. The drawback of this technology is mainly related to the upscaling due to the limitations in large-scale biomass supply, transportation, and treatment. Hence, from the economic point of view, the optimum electrical power output scale for this technology is still around 200 kWe [105]. Two-stage gasification-combustion stove with controlled air supply shown in Figure 4(g) provided considerably higher efficiency compared to the conventional stove designs with naturally aspirated air shown in Figure 4(h). Further experimental research is done with wide range of biomass raw materials and modified stoves (Figure 4(i)), and two-stage air-combustion in an incinerator design has shown good potential for upscaling (Figure 4(j)) and co-generation possibility.

Fig. 4. Biomass lab-scale project in Universitas Negeri Medan [101-104]

3.4 Medium/Large-Scale Research Activities

The development of commercial distributed power generation based on biomass renewable energy resources in Indonesia is encouraged and regulated by the Ministry of Energy and Mineral Resources Regulation No. 12/2019 [8]. However, the number of medium and large-scale power generation plants from biomass are still very limited and do not utilize the vast biomass waste materials generated from industrial and agricultural processing. Currently, most of the power generation from palm oil mills depends on direct biomass combustion in steam boilers to drive externally fired steam turbine. Gas turbines can also be operated in eternally fired manner using closed system supercritical carbon dioxide as the working fluid [106]. Some of the steam from the boiler is also needed for the production process of palm oil [107]. Thermal heat loses at the boiler chimney is not significant, however, it can still be recovered using externally fired engines such as Stirling engine [108]. Techno-economic study showed that distributed generation power plant based on gasification-IC engine generation can be feasible and competitive compared to the current steam-based generation systems [109]. Some of the recent medium and large-scale biomass power plant establishments are summarized in Table 1. Most of the biomass in the recent establishments is from oil palm industry waste, as well as, other agriculture waste such as rice husk, corncob, bamboo and bagasse compared to wood waste from furniture industry that was heavily utilized in older projects. The General Directorate of Renewable Energy and Energy Conservation under the Ministry of Energy and Mineral Resources has announced in 2018 the launch of several distributed generation biomass power plants (PLTBm). Introducing a 15 MW power generation based on biomass gasification of wide range of agriculture waste is a new step towards the large-scale implementation of gasification technology with better control of pollutant emissions [110]. However, majority of the announced projects still utilize steam boilers with direct biomass combustion as it is well established in Indonesia for the past two decades with proven reliability. One of the largest establishments was announced back in 2016 utilizing palm shell waste from oil palm industry with output electrical generation capacity of 30MW in Kalimantan [111].

Table 1
Recent development of biomass-based power plants in Indonesia

No	Location	Capacity	Biomass	Technology	COD	Ref.
1	Kalimantan Barat	15 MW	Palm shell	Gasification	2018	[110]
			Rice husk, Corncob, Sugarcane Bagasse			
		2x10 MW	Palm Shell	Combustion	N.D	
		4 MW	Palm shell	Combustion	N.D	
		1x15 MW	Palm shell	Combustion	N.D	
2	Kalimantan Tengah	30 MW	Palm shell	Combustion	2016	[111]
3	Mentawai, Sumatera Barat	300 kW	Bamboo	Combustion	2018	[112]
		150 kW	Bamboo	Combustion	N.D	
4	Sumatera Utara	2x15 MW	Palm shell, Corncob, Sawdust, Rice husk	Combustion	2012	[113]
		1x9,9 MW	Rubber wood	Combustion	2020	
		1x15 MW	Rubber wood	Combustion	N.D	
5	Jambi	10 MW	Palm shell	Combustion	N.D	[114]
6	Cilegon	1x15 MW	Palm shell	Combustion	N.D	[115]
7	Nias, Sumatera Utara	18 MW	Bamboo	Combustion	N.D	[116]
8	Sumba	1 MW	Bamboo, Wood chips	Combustion	N.D	[117]
9	Bali	150 kW	Wood pellet	Combustion	N.D	[118]
10	Sulawesi Tengah		Corncob	Combustion	N.D	[119]
11	Sumatera Selatan	3 MW	Rice husk	Combustion	N.D	[120]

COD: commercial operating date
N.D: not detected

4. Closing Remarks

Indonesia has one of the largest populations in the world with vast off-grade rural places. However, the electrification program has significantly progressed in the past few years, but with heavy reliance on short-term distribution generation. Issues have been raised as these projects are prone to fail due to the lack of long-term support from the government. One of the potential solutions is to allow the private sector to manage such projects with suitable monitoring policy. In general, the energy security index that covers wider range of energy poverty aspects other than the availability has shown steady annual elevation of about 3%.

The energy mix in Indonesia is still heavily relying on fossil fuels especially coal that still covers half of the energy supply for electricity generation. Predictions showed that the contribution of renewable energy to the national energy mix will still be less than coal by the year 2050 if the business-as-usual model is followed, and the dominance of renewable energy (up to 58%) can only be achieved if the government is committed to the low-carbon policy. For the short-term, increasing natural gas share and government support for renewable energy projects is essential to achieve the initial greenhouse reduction INDC target.

Biomass energy can play major role in the annual greenhouse emissions in Indonesia with vast forestry areas that can provide high carbon storage potential. Recently, forest and peatland degradation and forest fires have contributed up to nearly 60% of the annual greenhouse emissions. The current government policies were shown to be inadequate in controlling illegal logging and illegal land clearing with open fire. The fast growth of palm oil industry is another issue that requires the design of dedicated new government policies to replace the old policies. ISPO is an ambitious government policy that needs to be carefully implemented to avoid conflict between central and local government policies. The production of liquid biofuels such as biodiesel and bio-ethanol from food resources raw materials have been under the debate. Liquid biofuel production industry has grown significantly in the past two decades with aggressive government support and incentives to increase the biofuels share mainly in transportation sector.

The research on solid biomass waste from a food and furniture industries utilization included the direct conversion into other fuel forms using thermochemical (pyrolysis, gasification and liquefaction), fermentation and chemical conversion. However, most of these researches have not been commercialized with the exception of liquid biofuels chemical production. On the other hand, upgrading the quality of low-grade solid waste biomass into higher quality pellets and briquettes through torrefaction and carbonization were commercialized in small scales and shown good economic feasibility to compete with the low-grade coal in the local markets. For medium and large-scales, biomass power plants (PLTBm) industry has grown rapidly in the past 5 years, utilizing variety of waste resources such as palm shell, rice husk, corncob, bagasse, bamboo, sawdust and off-cut furniture wood. However, the utilization of biomass gasification technology is still very limited, while direct biomass combustion in boilers is still the dominant method for waste conversion into electricity.

Acknowledgement
The author is very grateful to the Universitas Negeri Medan for financial support through DIPA with Contract Number 104/UN33.8/KEP/PPKM/PT/2022. The author highly acknowledge support from the mechanical engineering workshop members, and also two final project students for their effort, participation and contribution to this project.

References

[1] United Nations Industrial Development Organization (UNIDO). "Accelerating clean energy through Industry 4.0 Manufacturing the next revolution." p. 56.

[2] Hidayatno, Akhmad, Arry Rahmawan Destyanto, and Christin Arauna Hulu. "Industry 4.0 technology implementation impact to industrial sustainable energy in Indonesia: A model conceptualization." *Energy Procedia* 156 (2019): 227-233. https://doi.org/10.1016/j.egypro.2018.11.133

[3] Nasional, D.E. "Indonesia energy outlook 2019." Jakarta: Sekretariat Jenderal Dewan Energi Nasional.

[4] Statistical Yearbook of Indonesia.

[5] Widyaparaga, Adhika, Bertha Maya Sopha, Arief Budiman, Imam Muthohar, Indra Chandra Setiawan, Alia Lindasista, Joewono Soemardjito, and Kazutaka Oka. "Scenarios analysis of energy mix for road transportation sector in Indonesia." *Renewable and Sustainable Energy Reviews* 70 (2017): 13-23. https://doi.org/10.1016/j.rser.2016.11.206

[6] Irawan, M. Zudhy, Prawira F. Belgiawan, Adhika Widyaparaga, Arief Budiman, Imam Muthohar, and Bertha M. Sopha. "A market share analysis for hybrid cars in Indonesia." *Case studies on transport policy* 6, no. 3 (2018): 336-341. https://doi.org/10.1016/j.cstp.2017.09.003

[7] Jayed, M. H., H. H. Masjuki, M. A. Kalam, T. M. I. Mahlia, M. Husnawan, and A. M. Liaquat. "Prospects of dedicated biodiesel engine vehicles in Malaysia and Indonesia." *Renewable and Sustainable Energy Reviews* 15, no. 1 (2011): 220-235. https://doi.org/10.1016/j.rser.2010.09.002

[8] President Regulation No. (73) year (2019) https://www.hukumonline.com/pusatdata/

[9] Huda, Muhammad, Muhammad Aziz, and Koji Tokimatsu. "The future of electric vehicles to grid integration in Indonesia." *Energy Procedia* 158 (2019): 4592-4597. https://doi.org/10.1016/j.egypro.2019.01.749

[10] Huda, Muhammad, Muhammad Aziz, and Koji Tokimatsu. "Potential ancillary services of electric vehicles (vehicle-to-grid) in Indonesia." *Energy Procedia* 152 (2018): 1218-1223. https://doi.org/10.1016/j.egypro.2018.09.172

[11] Aziz, Muhammad, and Muhammad Huda. "Application opportunity of vehicles-to-grid in Indonesian electrical grid." *Energy Procedia* 160 (2019): 621-626. https://doi.org/10.1016/j.egypro.2019.02.214

[12] Republic of Indonesia Energy Law number 30 Year 2007. http://jdih.esdm.go.id/peraturan/uu-30-2007.pdf

[13] Electricity Supply Business Plan (RUPTL) 2019– 2028. "Keputusan Menteri ESDM No. 39K/20/MEM/2019." http://alpha.djk.esdm.go.id/pdf/RUPTL/2019%2003%2018%20Diseminasi%20RUPTL%202019-2028.pdf

[14] Erahman, Qodri Febrilian, Widodo Wahyu Purwanto, Mahmud Sudibandriyo, and Akhmad Hidayatno. "An assessment of Indonesia's energy security index and comparison with seventy countries." *Energy* 111 (2016): 364-376. https://doi.org/10.1016/j.energy.2016.05.100

[15] Derks, Milou, and Henny Romijn. "Sustainable performance challenges of rural microgrids: Analysis of incentives and policy framework in Indonesia." *Energy for Sustainable Development* 53 (2019): 57-70. https://doi.org/10.1016/j.esd.2019.08.003

[16] Sato, Tatsuro, Jun'ichiro Ide, M. Alhaqurahman Isa, Faisal Rahadian, Tokihiko Fujimoto, and Yukihiro Shimatani. "A challenge for sustainable electrification, respecting the local tradition in Ciptagelar Village, West Java, Indonesia: Complementary Approach with a Private Company." *Energy Procedia* 141 (2017): 368-372. https://doi.org/10.1016/j.egypro.2017.11.044

[17] Falentina, Anna T., and Budy P. Resosudarmo. "The impact of blackouts on the performance of micro and small enterprises: Evidence from Indonesia." *World Development* 124 (2019): 104635. https://doi.org/10.1016/j.worlddev.2019.104635

[18] International Energy Agency (IEA), Energy Access Outlook 2017: from Poverty to Prosperity. IEA, Paris. https://www.iea.org/reports/energy-access-outlook-2017

[19] Sambodo, Maxensius Tri, and Rio Novandra. "The state of energy poverty in Indonesia and its impact on welfare." *Energy Policy* 132 (2019): 113-121. https://doi.org/10.1016/j.enpol.2019.05.029

[20] McNeil, Michael A., Nihan Karali, and Virginie Letschert. "Forecasting Indonesia's electricity load through 2030 and peak demand reductions from appliance and lighting efficiency." *Energy for sustainable development* 49 (2019): 65-77. https://doi.org/10.1016/j.esd.2019.01.001

[21] Ministry of Communication and Information Technology of the Republic of Indonesia. "Guidelines for Smart City Master Plan - towards 100 Smart Cities Movement." (2017).

[22] Mahesa, Restu, Gatot Yudoko, and Yudo Anggoro. "Dataset on the sustainable smart city development in Indonesia." *Data in brief* 25 (2019): 104098. https://doi.org/10.1016/j.dib.2019.104098

[23] Sugiawan, Yogi, and Shunsuke Managi. "Public acceptance of nuclear power plants in Indonesia: Portraying the role of a multilevel governance system." *Energy Strategy Reviews* 26 (2019): 100427. https://doi.org/10.1016/j.esr.2019.100427

[24] Kurniawan, Robi, and Shunsuke Managi. "Coal consumption, urbanization, and trade openness linkage in Indonesia." *Energy Policy* 121 (2018): 576-583. https://doi.org/10.1016/j.enpol.2018.07.023

[25] Dutu, Richard. "Challenges and policies in Indonesia's energy sector." *Energy Policy* 98 (2016): 513-519. https://doi.org/10.1016/j.enpol.2016.09.009

[26] Purwanto, Widodo Wahyu, Yuswan Muharam, Yoga Wienda Pratama, Djoni Hartono, Harimanto Soedirman, and Rezki Anindhito. "Status and outlook of natural gas industry development in Indonesia." *Journal of Natural Gas Science and Engineering* 29 (2016): 55-65. https://doi.org/10.1016/j.enpol.2016.09.009

[27] Acquah-Andoh, Elijah, Herdi A. Putra, Augustine O. Ifelebuegu, and Andrews Owusu. "Coalbed methane development in Indonesia: Design and economic analysis of upstream petroleum fiscal policy." *Energy Policy* 131 (2019): 155-167. https://doi.org/10.1016/j.enpol.2019.04.035

[28] Swainson, Luke, and Sango Mahanty. "Green economy meets political economy: Lessons from the "Aceh Green" initiative, Indonesia." *Global environmental change* 53 (2018): 286-295. https://doi.org/10.1016/j.gloenvcha.2018.10.009

[29] United Nations Framework Convention on Climate Change (UNFCCC): submissions of INDC. https://www4.unfccc.int/sites/submissions/INDC/Submission Pages/submissions.aspx

[30] Handayani, Kamia, Yoram Krozer, and Tatiana Filatova. "Trade-offs between electrification and climate change mitigation: An analysis of the Java-Bali power system in Indonesia." *Applied energy* 208 (2017): 1020-1037. https://doi.org/10.1016/j.apenergy.2017.09.048

[31] Al Irsyad, Muhammad Indra, Anthony Halog, Rabindra Nepal, and Deddy Priatmodjo Koesrindartoto. "Economical and environmental impacts of decarbonisation of Indonesian power sector." *Journal of environmental management* 259 (2020): 109669. https://doi.org/10.1016/j.jenvman.2019.109669

[32] Sewucipto, Sanjaya, and Triyogi Yuwono. "The Influence of Upstream Installation of D-53 Type Cylinder on the Performance of Savonius Turbine." *Journal of Advanced Research in Experimental Fluid Mechanics and Heat Transfer* 3, no. 1 (2021): 36-47.

[33] Maulidia, Martha, Paul Dargusch, Peta Ashworth, and Fitrian Ardiansyah. "Rethinking renewable energy targets and electricity sector reform in Indonesia: A private sector perspective." *Renewable and Sustainable Energy Reviews* 101 (2019): 231-247. https://doi.org/10.1016/j.rser.2018.11.005

[34] Kusakana, K., J. L. Munda, and A. A. Jimoh. "Economic and environmental analysis of micro hydropower system for rural power supply." In *2008 IEEE 2nd International Power and Energy Conference*, pp. 441-444. IEEE, 2008. https://doi.org/10.1109/PECON.2008.4762516

[35] Gokhale, Pritesh, Abhijit Date, Aliakbar Akbarzadeh, Putra Bismantolo, Ahmad Fauzan Suryono, Afdhal Kurniawan Mainil, and Agus Nuramal. "A review on micro hydropower in Indonesia." *Energy Procedia* 110 (2017): 316-321. https://doi.org/10.1016/j.egypro.2017.03.146

[36] Alhamid, M. Idrus, Yunus Daud, Arief Surachman, Agus Sugiyono, H. B. Aditya, and T. M. I. Mahlia. "Potential of geothermal energy for electricity generation in Indonesia: A review." *Renewable and Sustainable Energy Reviews* 53 (2016): 733-740. https://doi.org/10.1016/j.rser.2015.09.032
[37] Daud, Yunus, Wambra Aswo Nuqramadha, Fikri Fahmi, Rhyno Senbyla Sesesega, Surya Aji Pratama, and Arif Munandar. "Resistivity characterization of the Arjuno-Welirang volcanic geothermal system (Indonesia) through 3-D Magnetotelluric inverse modeling." *Journal of Asian Earth Sciences* 174 (2019): 352-363. https://doi.org/10.1016/j.jseaes.2019.01.033
[38] Pambudi, Nugroho Agung. "Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy." *Renewable and Sustainable Energy Reviews* 81 (2018): 2893-2901. https://doi.org/10.1016/j.rser.2017.06.096
[39] Alawi, Omer A., and Haslinda Mohamed Kamar. "Performance of Solar Thermal Collector Using Multi-Walled Carbon Nanotubes: Simulation Study." *Journal of Advanced Research in Micro and Nano Engineering* 2, no. 1 (2020): 12-21.
[40] Abdalla, Abakar Yousif, Zwalnan Selfa Johnson, Shanmugam Anandan, Chan Andy Tak-Yee, and Su Yuehong. "A Numerical Evaluation of the Effect of Building Thermal Load on the Overall Performance Characteristic of a Grid-Coupled PV/T Energy System." *Journal of Advanced Research in Numerical Heat Transfer* 4, no. 1 (2021): 32-43.
[41] Kennedy, Sean F. "Indonesia's energy transition and its contradictions: Emerging geographies of energy and finance." *Energy research & social science* 41 (2018): 230-237. https://doi.org/10.1016/j.erss.2018.04.023
[42] Burke, Paul J., Jinnie Widnyana, Zeba Anjum, Emma Aisbett, Budy Resosudarmo, and Kenneth GH Baldwin. "Overcoming barriers to solar and wind energy adoption in two Asian giants: India and Indonesia." *Energy Policy* 132 (2019): 1216-1228. https://doi.org/10.1016/j.enpol.2019.05.055
[43] Manaf, Norhuda Abdul, and Zahrul Faizi Mohd Shadzalli. "Waste-Energy-Climate Nexus Perspective Towards Circular Economy: A Mini-Review." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 26, no. 1 (2022): 31-41. https://doi.org/10.37934/araset.26.1.3141
[44] Ministry of Environment and Forestry, 2017. Indonesia's Third National Communication under the United Nations Framework Convention on Climate Change (UNFCCC).
[45] Tacconi, Luca, and Muhammad Zahrul Muttaqin. "Policy forum: Institutional architecture and activities to reduce emissions from forests in Indonesia." *Forest Policy and Economics* 108 (2019): 101980. https://doi.org/10.1016/j.forpol.2019.101980
[46] Meehan, Fiona, Luca Tacconi, and Kushartati Budiningsih. "Are national commitments to reducing emissions from forests effective? Lessons from Indonesia." *Forest Policy and Economics* 108 (2019): 101968. https://doi.org/10.1016/j.forpol.2019.101968
[47] Tacconi, Luca, and Muhammad Zahrul Muttaqin. "Reducing emissions from land use change in Indonesia: An overview." *Forest Policy and Economics* 108 (2019): 101979. https://doi.org/10.1016/j.forpol.2019.101979
[48] Cameron, Clint, Lindsay B. Hutley, Daniel A. Friess, and Ben Brown. "High greenhouse gas emissions mitigation benefits from mangrove rehabilitation in Sulawesi, Indonesia." *Ecosystem Services* 40 (2019): 101035. https://doi.org/10.1016/j.ecoser.2019.101035
[49] Alisjahbana, Armida S., and Jonah M. Busch. "Forestry, forest fires, and climate change in Indonesia." *Bulletin of Indonesian Economic Studies* 53, no. 2 (2017): 111-136. https://doi.org/10.1080/00074918.2017.1365404
[50] Edwards, Ryan B., Rosamond L. Naylor, Matthew M. Higgins, and Walter P. Falcon. "Causes of Indonesia's forest fires." *World Development* 127 (2020): 104717. https://doi.org/10.1016/j.worlddev.2019.104717
[51] Rulli, Maria Cristina, Stefano Casirati, Jampel Dell'Angelo, Kyle Frankel Davis, Corrado Passera, and Paolo D'Odorico. "Interdependencies and telecoupling of oil palm expansion at the expense of Indonesian rainforest." *Renewable and Sustainable Energy Reviews* 105 (2019): 499-512. https://doi.org/10.1016/j.rser.2018.12.050
[52] Lam, Wan Yee, Michal Kulak, Sarah Sim, Henry King, Mark AJ Huijbregts, and Rebecca Chaplin-Kramer. "Greenhouse gas footprints of palm oil production in Indonesia over space and time." *Science of the Total Environment* 688 (2019): 827-837. https://doi.org/10.1016/j.scitotenv.2019.06.377
[53] Zulkifli, Mohd Zul Amzar, Azfarizal Mukhtar, Muhammad Faizulizwan Mohamad Fadli, Anis Muneerah Shaiful Bahari, Akihiko Matsumoto, and Halina Misran. "CFD Simulation of CO2 and Methane Adsorption at Various Temperature for MOF-5 using Dual-site and Single-site Langmuir Model." *CFD Letters* 13, no. 10 (2021): 1-10. https://doi.org/10.37934/cfdl.13.10.110
[54] BPS, Statistik Indonesia, Badan Pusat Statistik, Jakarta, (2007).
[55] BPS, Statistik DAK (Ed.), Statistik Indonesia 2005/2006, Badan Pusat Statistik, Jakarta, (2006).
[56] KESDM-RI, Keputusan MEnteri Energi dan Sumber Daya MIneral Nomor 3175 K/ 10/MEM/2007 tentang Pengugasan PT Pertamina (Persero) dan Penetapan Daerah Tertentu dalam Penyediaan and Pendistribusian Liquefed Petroleum Gas Tabung 3 Kilogram Tahun 2007, Indonesia, (2007).

[57] Astuti, Septin Puji, Rosie Day, and Steven B. Emery. "A successful fuel transition? Regulatory instruments, markets, and social acceptance in the adoption of modern LPG cooking devices in Indonesia." *Energy Research & Social Science* 58 (2019): 101248. https://doi.org/10.1016/j.erss.2019.101248

[58] Kurniawan, Robi, Yogi Sugiawan, and Shunsuke Managi. "Cleaner energy conversion and household emission decomposition analysis in Indonesia." *Journal of Cleaner Production* 201 (2018): 334-342. https://doi.org/10.1016/j.jclepro.2018.08.051

[59] Bedi, Arjun S., Robert Sparrow, and Luca Tasciotti. "The impact of a household biogas programme on energy use and expenditure in East Java." *Energy Economics* 68 (2017): 66-76. https://doi.org/10.1016/j.eneco.2017.09.006

[60] Bedi, Arjun S., Robert Sparrow, and Luca Tasciotti. "Indonesia's Domestic Biogas Programme–Household panel survey data." *Data in brief* 17 (2018): 1388-1390. https://doi.org/10.1016/j.dib.2018.02.083

[61] Putra, R. Ahmad Romadhoni Surya, Zhen Liu, and Mogens Lund. "The impact of biogas technology adoption for farm households–Empirical evidence from mixed crop and livestock farming systems in Indonesia." *Renewable and Sustainable Energy Reviews* 74 (2017): 1371-1378. https://doi.org/10.1016/j.rser.2016.11.164

[62] Silaen, Mariana, Richard Taylor, Stefan Bößner, Annela Anger-Kraavi, Unnada Chewpreecha, Alessandro Badinotti, and Takeshi Takama. "Lessons from Bali for small-scale biogas development in Indonesia." *Environmental Innovation and Societal Transitions* 35 (2020): 445-459. https://doi.org/10.1016/j.eist.2019.09.003

[63] Andriani, Dian, Arini Wresta, Aep Saepudin, and Budi Prawara. "A review of recycling of human excreta to energy through biogas generation: Indonesia case." *Energy Procedia* 68 (2015): 219-225. https://doi.org/10.1016/j.egypro.2015.03.250

[64] Lestari, Prieskarinda, and Yulinah Trihadiningrum. "The impact of improper solid waste management to plastic pollution in Indonesian coast and marine environment." *Marine pollution bulletin* 149 (2019): 110505. https://doi.org/10.1016/j.marpolbul.2019.110505

[65] Putrasari, Yanuandri, Achmad Praptijanto, Widodo Budi Santoso, and Ocktaeck Lim. "Resources, policy, and research activities of biofuel in Indonesia: A review." *Energy Reports* 2 (2016): 237-245. https://doi.org/10.1016/j.egyr.2016.08.005

[66] Simangunsong, B. C. H., V. J. Sitanggang, E. G. T. Manurung, A. Rahmadi, G. A. Moore, L. Aye, and A. H. Tambunan. "Potential forest biomass resource as feedstock for bioenergy and its economic value in Indonesia." *Forest Policy and Economics* 81 (2017): 10-17. https://doi.org/10.1016/j.forpol.2017.03.022

[67] KNRT. Buku Putih Penelitian. "Pengembangan dan Penerapan Ilmu Pengetahuan dan Teknologi Bidang Sumber Energi Barudan Terbarukanuntuk Mendukung Keamanan Ketersediaan Energi Tahun 2025." Ministry of Research and Technology, Jakarta (2006).

[68] Aryapratama, Rio, and Stefan Pauliuk. "Estimating in-use wood-based materials carbon stocks in Indonesia: Towards a contribution to the national climate mitigation effort." *Resources, Conservation and Recycling* 149 (2019): 301-311. https://doi.org/10.1016/j.resconrec.2019.06.010

[69] Astari, Annisa Joviani, and Jon C. Lovett. "Does the rise of transnational governance 'hollow-out' the state? Discourse analysis of the mandatory Indonesian sustainable palm oil policy." *World Development* 117 (2019): 1-12. https://doi.org/10.1016/j.worlddev.2018.12.012

[70] Schoneveld, George C., Selma Van Der Haar, Dian Ekowati, Agus Andrianto, Heru Komarudin, Beni Okarda, Idsert Jelsma, and Pablo Pacheco. "Certification, good agricultural practice and smallholder heterogeneity: Differentiated pathways for resolving compliance gaps in the Indonesian oil palm sector." *Global Environmental Change* 57 (2019): 101933. https://doi.org/10.1016/j.gloenvcha.2019.101933

[71] Papilo, Petir, Erliza Hambali, and Imas S. Sitanggang. "Sustainability index assessment of palm oil-based bioenergy in Indonesia." *Journal of cleaner production* 196 (2018): 808-820. https://doi.org/10.1016/j.jclepro.2018.06.072

[72] Hasan, Muhammad H., TM Indra Mahlia, and Hadi Nur. "A review on energy scenario and sustainable energy in Indonesia." *Renewable and sustainable energy reviews* 16, no. 4 (2012): 2316-2328. https://doi.org/10.1016/j.rser.2011.12.007

[73] Singh, Rajbeer, and Andri D. Setiawan. "Biomass energy policies and strategies: Harvesting potential in India and Indonesia." *Renewable and Sustainable Energy Reviews* 22 (2013): 332-345. https://doi.org/10.1016/j.rser.2013.01.043

[74] Yoo, Heung-Min, Se-Won Park, Yong-Chil Seo, and Ki-Heon Kim. "Applicability assessment of empty fruit bunches from palm oil mills for use as bio-solid refuse fuels." *Journal of environmental management* 234 (2019): 1-7. https://doi.org/10.1016/j.jenvman.2018.11.035

[75] Ministry of Energy and Mineral Resource (ESDM). "Timnas BBN Gelar Workshop Sosialisasi Pengembangan Bahan Bakar Nabati (BBN)."

[76] Widodo, Yudi, Sri Wahyuningsih, and Jonathan Newby. "Fuelling cassava development to meet the greater demand for food and bio-fuel in Indonesia." *Energy Procedia* 65 (2015): 386-394. https://doi.org/10.1016/j.egypro.2015.01.068

[77] Khatiwada, Dilip, and Semida Silveira. "Scenarios for bioethanol production in Indonesia: How can we meet mandatory blending targets?." *Energy* 119 (2017): 351-361. https://doi.org/10.1016/j.energy.2016.12.073

[78] Khatiwada, Dilip, Bharadwaj K. Venkata, Semida Silveira, and Francis X. Johnson. "Energy and GHG balances of ethanol production from cane molasses in Indonesia." *Applied Energy* 164 (2016): 756-768. https://doi.org/10.1016/j.apenergy.2015.11.032

[79] Widodo, Yudi, Sri Wahyuningsih, and Aya Ueda. "Sweet potato production for bio-ethanol and food related industry in indonesia: Challenges for sustainability." *Procedia Chemistry* 14 (2015): 493-500. https://doi.org/10.1016/j.proche.2015.03.066

[80] Jusuf, Muhammad, and Erliana Ginting. "The prospects and challenges of sweet potato as bio-ethanol source in Indonesia." *Energy Procedia* 47 (2014): 173-179. https://doi.org/10.1016/j.egypro.2014.01.211

[81] Suryaningsih, Rahayu. "Bioenergy plants in Indonesia: Sorghum for producing bioethanol as an alternative energy substitute of fossil fuels." *Energy Procedia* 47 (2014): 211-216. https://doi.org/10.1016/j.egypro.2014.01.216

[82] Suntana, Asep S., Kristiina A. Vogt, Eric C. Turnblom, and Ravi Upadhye. "Bio-methanol potential in Indonesia: forest biomass as a source of bio-energy that reduces carbon emissions." *Applied energy* 86 (2009): S215-S221. https://doi.org/10.1016/j.apenergy.2009.05.028

[83] Silitonga, A. S., A. E. Atabani, T. M. I. Mahlia, H. H. Masjuki, Irfan Anjum Badruddin, and S. Mekhilef. "A review on prospect of Jatropha curcas for biodiesel in Indonesia." *Renewable and Sustainable Energy Reviews* 15, no. 8 (2011): 3733-3756. https://doi.org/10.1016/j.rser.2011.07.011

[84] ten Kate, Joeri, Ruud Teunter, Ratih Dyah Kusumastuti, and Dirk Pieter van Donk. "Bio-diesel production using mobile processing units: A case in Indonesia." *Agricultural Systems* 152 (2017): 121-130. https://doi.org/10.1016/j.agsy.2016.12.015

[85] Harahap, Fumi, Semida Silveira, and Dilip Khatiwada. "Cost competitiveness of palm oil biodiesel production in Indonesia." *Energy* 170 (2019): 62-72. https://doi.org/10.1016/j.energy.2018.12.115

[86] Biddinika, Muhammad Kunta, Mochamad Syamsiro, Arip Nur Hadiyanto, Zahrul Mufrodi, and Fumitake Takahashi. "Technology for public outreach of fuel oil production from municipal plastic wastes." *Energy Procedia* 142 (2017): 2797-2801. https://doi.org/10.1016/j.egypro.2017.12.424

[87] Febriansyah, Hermawan, Ahmad Agus Setiawan, Kutut Suryopratomo, and Agus Setiawan. "Gama stove: biomass stove for palm kernel shells in Indonesia." *Energy Procedia* 47 (2014): 123-132. https://doi.org/10.1016/j.egypro.2014.01.205

[88] Maniatis, K. "Biomass gasification in Indonesia." *Biomass* 18, no. 3-4 (1989): 221-239. https://doi.org/10.1016/0144-4565(89)90035-8

[89] Sansaniwal, S. K., K. Pal, M. A. Rosen, and S. K. Tyagi. "Recent advances in the development of biomass gasification technology: A comprehensive review." *Renewable and sustainable energy reviews* 72 (2017): 363-384. https://doi.org/10.1016/j.rser.2017.01.038

[90] Kusumaningrum, Wida B., and Sasa Sofyan Munawar. "Prospect of bio-pellet as an alternative energy to substitute solid fuel based." *Energy Procedia* 47 (2014): 303-309. https://doi.org/10.1016/j.egypro.2014.01.229

[91] Alamsyah, Rizal, Enny Hawani Loebis, Eko Susanto, Lukman Junaidi, and Nobel Christian Siregar. "An experimental study on synthetic gas (syngas) production through gasification of Indonesian biomass pellet." *Energy Procedia* 65 (2015): 292-299. https://doi.org/10.1016/j.egypro.2015.01.053

[92] Daniyanto, Sutidjan, and Budiman A. Deendarlianto. "Torrefaction of Indonesian sugar-cane bagasse to improve bio-syngas quality for gasification process." *Energy Procedia* 68 (2015): 157-166. https://doi.org/10.1016/j.egypro.2015.03.244

[93] Basu, Prabir. *Biomass gasification, pyrolysis and torrefaction: practical design and theory*. Academic press, 2018. https://doi.org/10.1016/C2011-0-07564-6

[94] Sembiring, Kiky C., Nino Rinaldi, and Sabar P. Simanungkalit. "Bio-oil from fast pyrolysis of empty fruit bunch at various temperature." *Energy procedia* 65 (2015): 162-169. https://doi.org/10.1016/j.egypro.2015.01.052

[95] Pradana, Yano Surya, Muhamad Hartono, Laras Prasakti, and Arief Budiman. "Effect of calcium and magnesium catalyst on pyrolysis kinetic of Indonesian sugarcane bagasse for biofuel production." *Energy Procedia* 158 (2019): 431-439. https://doi.org/10.1016/j.egypro.2019.01.128

[96] Syamsiro, M., H. Saptoadi, B. H. Tambunan, and N. A. Pambudi. "A preliminary study on use of cocoa pod husk as a renewable source of energy in Indonesia." *Energy for Sustainable development* 16, no. 1 (2012): 74-77. https://doi.org/10.1016/j.esd.2011.10.005

[97] Susilaningsih, Dwi, Louis S. Sirait, Khairul Anam, M. Sidiq Habibi, and Bambang Prasetya. "Possible application of biohydrogen technologies as electricity sources in Indonesian remote areas." *International journal of hydrogen energy* 39, no. 33 (2014): 19400-19405. https://doi.org/10.1016/j.ijhydene.2014.08.073

[98] Susilawati, Rita, Sam L. Papendick, Patrick C. Gilcrease, Joan S. Esterle, Suzanne D. Golding, and Tennille E. Mares. "Preliminary investigation of biogenic gas production in Indonesian low rank coals and implications for a renewable energy source." *Journal of Asian Earth Sciences* 77 (2013): 234-242. https://doi.org/10.1016/j.jseaes.2013.08.024

[99] Hendroko, Roy, Tony Liwang, Praptiningsih G. Adinurani, Leopold O. Nelwan, Yosephianus Sakri, and Satriyo K. Wahono. "The modification for increasing productivity at hydrolysis reactor with Jatropha curcas Linn capsule husk as bio-methane feedstocks at two stage digestion." *Energy Procedia* 32 (2013): 47-54. https://doi.org/10.1016/j.egypro.2013.05.007

[100] Adinurani, Praptiningsih G., Tony Liwang, Leopold O. Nelwan, Yosephianus Sakri, Satriyo K. Wahono, and Roy Hendroko. "The study of two stages anaerobic digestion application and suitable bio-film as an effort to improve bio-gas productivity from Jatropha Curcas Linn capsule husk." *Energy Procedia* 32 (2013): 84-89. https://doi.org/10.1016/j.egypro.2013.05.011

[101] Simanjuntak, Janter P., and Z. A. Zainal. "Experimental study and characterization of a two-compartment cylindrical internally circulating fluidized bed gasifier." *Biomass and Bioenergy* 77 (2015): 147-154. https://doi.org/10.1016/j.biombioe.2015.03.023

[102] Simanjuntak, Janter P., K. A. Al-attab, and Z. A. Zainal. "Hydrodynamic Flow Characteristics in an Internally Circulating Fluidized Bed Gasifier." *Journal of Energy Resources Technology* 141, no. 3 (2019). https://doi.org/10.1115/1.4041092

[103] Simanjuntak, JP, Tambunan BH, Daryanto E. "Karakterisasi Biomassa Lokal Sebagai Bahan Bakar Alternatif Menggunakan Reaktor Penggas Tipe Downdraft." Seminar Nasional Art, Sains dan Teknologi, Gorontalo.

[104] Simanjuntak, Janter P., Eka Daryanto, and Bisrul Hapis Tambunan. "Producer gas production of Indonesian biomass in fixed-bed downdraft gasifier as an alternative fuels for internal combustion engines." In *Journal of Physics: Conference Series*, vol. 970, no. 1, p. 012019. IOP Publishing, 2018. https://doi.org/10.1088/1742-6596/970/1/012019

[105] Situmorang, Yohanes Andre, Zhongkai Zhao, Akihiro Yoshida, Abuliti Abudula, and Guoqing Guan. "Small-scale biomass gasification systems for power generation (< 200 kW class): A review." *Renewable and sustainable energy reviews* 117 (2020): 109486. https://doi.org/10.1016/j.rser.2019.109486

[106] Ken, Chong Zhi, and Syamimi Saadon. "Performance Analysis of Supercritical Carbon Dioxide-Brayton Cycle for Waste Heat Recovery using Aspen Plus." *Journal of Advanced Research in Applied Mechanics* 93, no. 1 (2022): 8-12.

[107] Hanifarianty, Sherly, Siravit Pakdeechot, and Makatar Wae-hayee. "The Effects of Sterilization Time of FFB on Fruit-Bunch Separation and Crude Palm Oil Quality Using Direct Steaming." *Journal of Advanced Research in Applied Mechanics* 72, no. 1 (2020): 1-9. https://doi.org/10.37934/aram.72.1.19

[108] Rahman, Nik Kechik Mujahidah Nik Abdul, Syamimi Saadon, and Mohd Hasrizam Che Man. "Waste Heat Recovery of Biomass Based Industrial Boilers by Using Stirling Engine." *Journal of Advanced Research in Applied Mechanics* 81, no. 1 (2021): 1-10. https://doi.org/10.37934/aram.81.1.110

[109] You, Siming, Huanhuan Tong, Joel Armin-Hoiland, Yen Wah Tong, and Chi-Hwa Wang. "Techno-economic and greenhouse gas savings assessment of decentralized biomass gasification for electrifying the rural areas of Indonesia." *Applied Energy* 208 (2017): 495-510. https://doi.org/10.1016/j.apenergy.2017.10.001

[110] General Directorate of Renewable Energy and Energy Conservation. "The First Private Biomass PLT in West Kalimantan. Ministry of Energy and Mineral Resources."

[111] General Directorate of Renewable Energy and Energy Conservation. "PLN Build Power Supply Biomass Power Plant in Kalimantan. Ministry of Energy and Mineral Resources."

[112] Biomass Power Plant Inaugurated in Mentawai. REPUBLIKA.

[113] The Government Inaugurates Deli Serdang Biomass Power Plant. EKONOMI.

[114] General Directorate of Renewable Energy and Energy Conservation. Developing the EBT Market in Jambi, MEMR Cooperates with UNDP to Implement MTRE3 Project, Ministry of Energy and Mineral Resources.

[115] GSG operates five Biomass power plants, KONTAN.

[116] Several companies are targeting three renewable energy power generation projects from biomass. BISINIS.

[117] West Sumba Regency. West Sumba Regional Government Builds PLTBm In collaboration with PT. PLN, Government of Indonesia.

[118] Building Biomass PLT in Bali, SINDONEWS.

[119] Manado builds a biomass power plant, ANTARANEWS.

[120] Rice husk biomass power plant (PLTBm) in Ogan Ilir Regency, ANTARANEWS.

4-Bioenergy as an

ORIGINALITY REPORT

17%	0%	6%	15%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Leiden University Student Paper	1%
2	Submitted to Universitas Diponegoro Student Paper	1%
3	Submitted to Griffth University Student Paper	1%
4	Submitted to School of Business and Management ITB Student Paper	1%
5	Submitted to University of Nottingham Student Paper	1%
6	Submitted to Unizin, LLC Student Paper	1%
7	H.S. Ruiz, A. Sunarso, K. Ibrahim-Bathis, S.A. Murti, I. Budiarto. "GIS-AHP Multi Criteria Decision Analysis for the optimal location of solar energy plants at Indonesia", Energy Reports, 2020 Publication	1%

8	Submitted to Singapore Management University Student Paper	1 %
9	Submitted to National University of Singapore Student Paper	<1 %
10	Submitted to Queensland University of Technology Student Paper	<1 %
11	Submitted to University of Queensland Student Paper	<1 %
12	Submitted to Grenoble Ecole Management Student Paper	<1 %
13	Submitted to Australian National University Student Paper	<1 %
14	Submitted to University of Sydney Student Paper	<1 %
15	Submitted to Curtin University of Technology Student Paper	<1 %
16	Submitted to Universiti Teknologi Malaysia Student Paper	<1 %
17	Submitted to Institut Pertanian Bogor Student Paper	<1 %
18	Submitted to Padjadjaran University Student Paper	<1 %

19	Submitted to Rajarambapu Institute of Technology Student Paper	<1 %
20	Submitted to Nanyang Technological University Student Paper	<1 %
21	Submitted to Billy Blue Group Student Paper	<1 %
22	Submitted to Georgetown University Student Paper	<1 %
23	Muhammad Firdaus, Yulinah Trihadiningrum, Prieskarinda Lestari. "Microplastic pollution in the sediment of Jagir Estuary, Surabaya City, Indonesia", Marine Pollution Bulletin, 2020 Publication	<1 %
24	Submitted to Heriot-Watt University Student Paper	<1 %
25	Submitted to Monash University Student Paper	<1 %
26	Submitted to UC, Boulder Student Paper	<1 %
27	Submitted to CSU, Bakersfield Student Paper	<1 %
28	Submitted to Higher Education Commission Pakistan Student Paper	<1 %

29	Submitted to Murdoch University Student Paper	<1 %
30	Submitted to University of Edinburgh Student Paper	<1 %
31	Submitted to Babson College Student Paper	<1 %
32	Submitted to University of Glasgow Student Paper	<1 %
33	Submitted to University of Exeter Student Paper	<1 %
34	Submitted to Universitas Ibn Khaldun Student Paper	<1 %
35	Bismark Lopes Bahia, Thays Moura Santana, Caique Carvalho Medauar, Flávia Conceição Pinto et al. "Partition, correlation, and natural bioconcentration of iron, manganese, and zinc in cacao trees", Journal of Plant Nutrition, 2021 Publication	<1 %
36	Submitted to Wageningen University Student Paper	<1 %
37	Submitted to Coventry University Student Paper	<1 %
38	Submitted to Graduate Institute of International and Development Studies	<1 %

Student Paper

39	Hanni Wirawan, Yohanna M.L. Gultom. "The effects of renewable energy-based village grid electrification on poverty reduction in remote areas: The case of Indonesia", Energy for Sustainable Development, 2021 Publication	<1 %
40	Submitted to University of Dundee Student Paper	<1 %
41	Submitted to KTH - The Royal Institute of Technology Student Paper	<1 %
42	Submitted to Sriwijaya University Student Paper	<1 %
43	Submitted to University of Newcastle upon Tyne Student Paper	<1 %
44	Wayan G. Santika, Tania Urmee, Yeliz Simsek, Parisa A. Bahri, M. Anisuzzaman. "An assessment of energy policy impacts on achieving Sustainable Development Goal 7 in Indonesia", Energy for Sustainable Development, 2020 Publication	<1 %
45	devtest-en.inforang.com Internet Source	<1 %

46	Submitted to University of Melbourne Student Paper	<1 %
47	archive.org Internet Source	<1 %
48	Mustapha Yakubu Madaki, Steffen Muench, Harald Kaechele, Miroslava Bavorova. "Climate Change Knowledge and Perception among Farming Households in Nigeria", Research Square Platform LLC, 2022 Publication	<1 %
49	Submitted to UIN Sunan Ampel Surabaya Student Paper	<1 %
50	Submitted to Universitas Pendidikan Indonesia Student Paper	<1 %
51	Submitted to University of Witwatersrand Student Paper	<1 %
52	Submitted to Universitas Sebelas Maret Student Paper	<1 %
53	Microelectronics International, Volume 30, Issue 3 (2014-03-28) Publication	<1 %
54	Solomon Prince Nathaniel. "Ecological footprint, energy use, trade, and urbanization linkage in Indonesia", GeoJournal, 2020 Publication	<1 %

55	Submitted to University College London Student Paper	<1%
56	Submitted to University of Western Australia Student Paper	<1%
57	Submitted to University of Warwick Student Paper	<1%
58	"DD321 book 2 ISBN9781473031678", Open University Publication	<1%
59	Yayu Zuo, Lingling Kang, Keliang Wang. "An ultra-high special energy Mg-Ni seawater battery", Chemical Physics Letters, 2022 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		