Renewable and Sustainable Energy Reviews 144 (2021) 111027

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: http://www.elsevier.com/locate/rser

The political economy of oil supply in Indonesia and the implications for renewable energy development

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ARTICLE INFO

Keywords:
Oil
Geopolitics
Subsidy
Emissions
Renewable energy
Energy mix

ABSTRACT

A notable research gap in the Indonesian policy environment is the lack of discussion about its energy planning. This article addresses the problem by adopting a political economy approach to investigate the country's mix and security of energy supplies to 2050. A comprehensive review produces three project inquiries into the continued reliance on oil and implications of greater moves toward renewable sources of energy. A situation audit appraises Indonesia's place in the global politics of oil supply, its domestic logistics, its continuing oil subsidy, and positioning toward fossil fuel emissions and renewable energy. Shortcoming are identified in the nation's high dependency on fossil fuels and, in particular, oil imports; the extent of its oil subsidy; a lack of strategic oil buffers; insufficient attention to emissions; and contradictory policies towards renewable energy. The article concludes by presenting a research agenda to support the transition of Indonesia's energy mix and security to 2050.

1. Introduction

Indonesia, with 268 million people in 2019, is the world's fourth most populous country. It incorporates over 17,000 islands including nine large ones, covering 5.26 million square kilometers of land and sea [1]. With a GDP of USD1,042 billion, the archipelago has the largest economy in South East Asia, the 16th globally and the seventh in term of purchasing power parity [2]. It has enjoyed relatively stable economic growth of around 5% p. a. over the last decade, positioning it on this parameter below only China and India within the G20 economies. The emerging nation still relies heavily on fossil-based fuels, particularly oil. This orientation is likely to be long-term, since cheaper, mature energy resources are favored. More than half the oil is sourced from imports, creating vulnerability to geopolitical disruptions.

Being import-dependent, the government naturally focuses on securing oil access. As outlined by Yergin [3], 'energy security' requires the availability of sufficient quantity at affordable prices, implicating protection of the entire supply chain and its infrastructure. By another definition, energy security involves the alleviation of threats which are caused by, or have an impact on, a supply chain [3,4]. Policy should be directed to prevent and overcome conditions of insecurity [5,6] with the aim to provide sufficient energy for the wellbeing of inhabitants, without harmful effects on the environment [7].

Combustion of fossil-based fuels generates large quantities of carbon dioxide (CO_2) [8] which trap heat in the atmosphere and foster climate change [8–11]. In 2019, global emissions from coal, oil and gas were 14.3 $MtCO_2$, 12.4 $MtCO_2$ and 7.6 $MtCO_2$ respectively [12]. Accordingly, a country's energy supply should thus exhibit three main characteristics: low supply costs; continuity; and diminution of environmental impacts [13–15]. Cognizant of resource scarcity, security policy must now incorporate renewables [16], since they can substitute for fossil-based fuels and diversify sources [17,18]. However, major barriers in promoting their use to date have been high investment costs, strong competition from fossil fuels, feedstock availability and the logistics of supply [19].

A nation's energy mix is understood to be the combination of three primary sources engaged to meet domestic needs: fossil fuels, renewables, and nuclear power[1] [20]. Oil remains Indonesia's most significant component: in 2018, its share of total energy use was 38.8%, followed by coal at 33.0%, natural gas at 19.7%, and renewables with 8.6% [21]. Its current situation is characterized by: 1) high dependence on oil; 2) potential risk in securing the supply since the nation is more than 50% import-dependent; and 3) relatively minor exposure to renewables.

Given these conditions, a significant research and policy gap emerges around the following objective function: simply put, how can Indonesia plan for a secure and sustainable energy mix in the long run? As the first

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[1] This article is not positioned to enter into discussion of nuclear options.

https://doi.org/10.1016/j.rser.2021.111027
Received 9 September 2020; Received in revised form 11 March 2021; Accepted 21 March 2021
Available online 6 April 2021

point of reference, Rencana Umum Energi Nasional (RUEN), the national energy plan enabled by Presidential Regulation No. 22/2017, informs government inter-sectoral agencies in their policy-making to establish national energy security and sustainable development by:

- defining energy needs in the long run, taking into account economic and population growth;
- setting out energy supply targets for each primary energy source (in 2050, total primary energy supply (TPES) targets consist of fossil-based sources 69% and renewables 31%); and
- providing energy infrastructure development guidelines.

This article proposes an appraisal of current national management and its long-run prospects in establishing a secure and sustainable energy mix. In tackling the research question, it commences with a broad literature review of national energy dynamics to highlight the key strategic issues. This situation appraisal probes several key concerns regarding energy security and the mix, leading to findings contained in a discussion of potential national reform. Conclusions are composed around a series of future research initiatives.

2. Literature review

Studies of Indonesia's energy situation and security began with contributions of a group of experts published in Oocities.org [22]. Kristijo and Nugroho [23], Susandi [24], Muliadiredja [25], Sambodo [26], Nugroho [27] debated the mix and undertook projections to 2020, with an emphasis on fossil-based inputs. Since 2011, themes have multiplied, with more attention to diversification of sources, particularly renewables [28,29]. Over the last decade, four key strategic themes have arisen. We examine them from the micro to a macro standpoint covering: studies of existing fossil fuel dynamics; energy mix modelling; sustainability (renewable energy promotion and emission reduction); and overall energy policy.

Facing an abundance of *fossil-based energy studies*, often specifically-focused and emphasizing the oil industry, we can no more than summarize the leading investigations. Indonesia receives a low score from current observers regarding energy security [30–32]. The influence of foreign exchange transactions on oil imports has been appraised by Dewi and Sudirman [33]. Studies of the national energy subsidy have interested Lontoh, Clarke [34] and Yuliarmi, Sudirman [35], with policy options examined by the Indonesian Ministry of Energy and Mineral Resources [36], Mourougane [37], and Nugraheni, Hermawan [38]. The subsidy's impact on the national budget and economy has occupied Hasan [39], Nugroho, Amir [40], and Oktaviani, Hakim [41]. Fossil fuel energy subventions have arguably hindered development of renewables and energy efficiency [42,43]. Their gradual removal is necessary if progress is to be made toward national targets [42]. Trends in fossil fuel sectors explain Indonesia's reorientation from oil to coal as the key energy source to 2030 and even later [44]. Allegedly, such substitution increases economic performance [45]. Sugiyono [46] estimates that petroleum is expected to be the main energy supply in Indonesia until 2035, replaced afterwards by coal: in his opinion (more forward-looking than that of some other authors who have assessed fossil fuels), renewable energy is needed to overcome the energy deficit.

In *energy modelling*, Kumar [47], Mujiyanto and Tiess [48], Siagian, Yuwono [49], Deendarlianto, Widyaparaga [50] Daryono, Sugeng [51] and Mappangara and Warokka [52] examine ideas and scenarios to enhance renewables' share in the mix. Hartono, Hastuti [53] measured the changes in energy access in different household categories. Handayani, Krozer [54] explored long-range energy alternative planning (LEAP) scenarios for capacity expansion of the Java-Bali region electricity system. Purwanto, Pratama [55] present a multi-objective optimization model for the electricity system by considering technical changes and technology diffusion, notably for renewable electricity. They maintain that Indonesia should pursue all renewable options but still support coal and natural gas. Budi, Sarjiya [56] review uncertainty problems in power systems and the prospects of renewable energy to fulfil production targets considering uncertainty on the demand side, in power plant generation, transmission and distribution capacity, and around energy resources. They argue that Indonesia has good prospects and the ability to meet renewable targets.

Renewables and energy emissions emerge as problematic topics in several papers. Kholiq [57] discusses the claims of renewables: Indonesia has massive geothermal potential, approximately 28.91 GW, or about 40% of the world's reserve [58–60]. However, utilization is presently lower than 5%. For biofuels, the archipelago has a huge raw material supply, especially of biodiesel, due to the availability of land and many types of agricultural plantations such as oil palm [61,62]. Biofuel is one of the chief candidates to replace conventional fuels [63]. Oil palm is the most productive and cheapest source of vegetable oil for biodiesel [64] and Indonesia is the world's largest grower. Biomass is likewise abundant [65]. Addressing hydro power, Agung Wahyuono and Magenika Julian [66] highlight the impact of seasonal variations, but point out that solar capacity in Indonesia is stable throughout the year. Ribal, Babanin [67] present a wave energy assessment. In regard to energy output, average wind speed across the island chain is low, making it difficult to generate electricity on a large scale [68]. Several locations have strong potential, but remain undeveloped [69]. The effects of energy-based economic growth on CO_2 emissions have been explored by Darwanto, Santosa [70], Hadi and Jaka [71], Hwang and Yoo [72], Sandu, Yang [73], Traheka Erdyas and Tri [74]. Another inquiry by Den Elzen, Kuramochi [75] shows that the country is on track to achieve, or overachieve, its GHG emission reduction target as stated in its Nationally Determined Contribution (NDC) of 2016 [76,77] [2]).

Regarding *energy policy*, Santika, Anisuzzaman [78] investigated Indonesia's response to the 2015 United Nations Sustainable Development Goals (SDGs). They argued that the country should continue with its national plan (RUEN) to ensure that energy demand under the SDG regime will be met by 2030. Setyowati [79] and Burke, Widnyana [80] found that regulatory uncertainty, fluctuating decentralization processes, the recalcitrance of the monopoly energy provider (Perusahaan Listrik Negara – PLN), and its unwillingness to facilitate standardized power purchase agreements have become serious obstacles to the deployment of renewables. Sharvini, Noor [81] concluded that one of the factors influencing non-fossil energy support in Indonesia relates to the lack of awareness and coordination between central and local governments. Guild [82] contended that, if the country is serious in reducing its carbon footprint and developing a renewables sector, policy makers must contemplate how, sustainably, to finance the high initial capital costs.

Much useful and comparative commentary is therefore available, but how should all these publications be assessed? In their coverage of energy issues, three-quarters emphasize inputs (primary sources) while the remainder deal with outputs (transformation and emissions). Second, most inquiries concern certain aspects of energy variables, their interrelations, subsidies, modelling, and sectoral characteristics. The papers' focus on fossil versus renewable fuels is roughly half and half though, individually, oil-related issues capture most attention. Oil influences many facets of energy policies such as diversification or conversion to other sources, public assistance, and effectiveness of energy regulation.

Most significantly within this literature review, we failed to uncover

[2] The NDC is a national plan highlighting climate actions, including targets, policies and measures which governments can implement in response to global efforts to address climate change. In accordance with the Paris Agreement Article 4, Paragraph 2, it requires each country or party to the United Nations Framework Convention on Climate Change (UNFCCC) to prepare, communicate and monitor successive steps which it intends to achieve. The NDC thus involves pledges to mitigate GHG emissions.

any comprehensive research into the effectiveness of government policy around RUEN and the NDC. This absence goes to the heart of the political economy of oil supply in indonesia and the implications for renewable energy development. Reliance has been placed on fossil fuels, which appear entrenched in the medium- and long-terms. Coal and gas dominate the energy mix, while renewables are relatively overlooked. Yet, the two former sources are recognized as the main cause of GHG emissions' ability to produce global warming and climate change as expressed in the Paris Agreement objectives.

With this backdrop, the operative function, which in the long run seeks a secured and sustainable energy mix, can be probed by means of three project inquiries: 1) Is the country's oil usage actually a problem? 2) Can it continue in the longer term? and 3) What would be the situation were oil to retreat in favor of renewables in the energy mix?

3. Methodology

To furnish the inquiries with appropriate evidence, we undertake a situation audit and appraisal of oil in the Indonesian context through five progressive stages which analyze: i) the country's position within global energy politics; ii) contemporary oil supply logistics; iii) the government oil subsidy; iv) policy in GHG emission reduction; and v) the progress of renewable energy development. The political economy approach to these key issues examines how policy is used to manage scarce resources [83]; more especially, how political structures and interactions shape energy markets [84]. Political economy 'opens the black box' of decision-making by analyzing the role of institutions, interest groups and ideologies by identifying the factors that influence decision-making and accounting for the technical aspects of implementation through policy instruments [85]. 'Political economy' does not aim to determine the 'best' policy, but to identify the conflict attending decisions and the way it is handled in the governance system [86]. It admits the behavior of certain social groups (stakeholders) into the analysis of change [87].

We ground factual data relating to energy mix and security issues [84] by recognizing both ecological and existential scarcity based on Daly's theory of the steady-state economy (see Fig. 1) [88]. Herein, the interaction between economy and ecology is envisioned as that of an open, entropic physical system; a fund of service (income) from assets maintained by a throughput of energy, followed by depletion of nature's sources, ending with the pollution of its sinks. In this view, the energy cycle basically approaches a steady-state in which the ecosystem provides constant stocks, from which participants and agents should maximize benefits (i.e. service or income) and minimize throughput (costs and wastes which, in energy terms, are expressed as emissions).

4. Situation audit and appraisal

4.1. Indonesia within the global politics of oil supply

The world's proven oil reserves at the end of 2018 totaled 1,730 billion barrels, sufficient for 50 years' consumption based on current production rates [89]. If potential reserves are included, oil supply can meet demand until 2100 [90]. The OPEC holds 71.8% of these reserves [89], about two thirds of which are found in the Middle East and North African (MENA) regions [91]. Meanwhile, oil production from the Asia-Pacific zone will be insufficient to supply rising demand from developing Asian countries such as China, India and ASEAN [92]. To deal with this deficit, incremental imports will have to come from the Atlantic Basin [92]. The shale revolution is expected to turn the United States from an energy importer to a net exporter after 2020 as production of crude oil and natural gas exceeds domestic consumption[3] [93].

The world has been experiencing a global shift in the geography of energy driven by differential rates of population growth, urbanization, and economic development [94]. Oil demand in the OECD peaked in 2005 [95]. In these advanced countries, it began to fall gradually due to increasing end-use efficiency. However, demand in developing nations will probably outweigh this decline, given the scale of population and prospects of economic advance from China, India and the ASEAN [96].

The world economy slowed in 2018–2019 and entered a recession in 2020 due to the Covid-19 outbreak. Demand for oil is ebbing, while supply, already overabundant, is significantly increasing. In May 2020, the crude oil price in the United States dropped to nearly minus US$40 a barrel, the lowest on record, caused by a massive supply/demand mismatch [97,98]. Yet, from an environmental perspective, the positive impact of the pandemic in lowering CO_2 emissions might be short-lived [99,100].[4]

The oil market is inevitably entwined with competitive geopolitical factors.[5] On the supply side, OPEC, the MENA bloc, Russia and the United States are the dominant players. As to demand, China, OECD countries, India, and ASEAN form the largest markets. The issue concerning oil is not only about supply and demand, but also about its impacts on climate change. Inter-governmental conventions have been held annually through conferences of parties (COP). Some of the important milestones have been the Earth Summit in Rio de Janeiro (1992), the Kyoto Protocol (1997), the Copenhagen Accord (2009), the Doha Amendment (2012), and the Paris Agreement (2015). Despite these positive engagements, disruption comes in the form of dissent, or withdrawal from climate change agreements, leading to retardation of global mitigation efforts. Some major movements in oil-related geopolitics in recent years, including climate issues, are documented in Table 1.

The 1997 Kyoto Protocol was the first agreement made globally among nations. It committed participants to lessen GHG emissions. Developed countries pledged to binding targets. The United States did not take part in the Protocol, and Canada withdrew before the end of the first commitment period. The 2015 Paris Agreement is considered the most important treaty to limit an increase in the global average temperature to a maximum of 2 °C but, more critically, 1.5 °C above preindustrial revolution levels [117,118]. As the follow-up, delegates were obliged to submit NDCs, which set out each country's plan to counter global warming. As of June 1, 2020, the agreement had been ratified by 197 parties, including the United States, China, India, Russia, and the European Union [119]. However, the United States submitted to the United Nations formal notification of its withdrawal on November 4th, 2019, effective from November 4th, 2020. Now, under its new president, it will likely to rejoin the grouping in 2021.

In global business, BlackRock [120], the world's largest asset manager with nearly US$7 trillion in investments, is shifting its allocation policy towards a low-carbon economy in line with the Paris Agreement

[3] Depending on the outcome of the United States' new presidency over 2021–2024.

[4] The global financial crisis saw global CO_2 emissions decline by 1.4% in 2009, immediately followed by a growth of 5.1% in 2010. However, since the economic crisis associated with Covid-19 is more deeply anchored in constrained individual behavior, it also involves uncertainty about how long and deep the crisis and the recovery path will be, and therefore how CO_2 emissions will be affected.

[5] World crude oil prices are generally determined by global supply and demand [94,101,102]. OPEC has a significant influence on oil prices since it controls around 41% of total world crude production [103]. OPEC can affect the supply side by setting crude oil production targets, or quotas, for its members [103,104]. Nevertheless, the competitiveness of other big oil producers (such as Russia and US) when oil prices change can also be a factor that offset the influence of OPEC [103]. Other factors influencing world oil price are evident on the considerable impact of S&P crude oil index, regarded as a 'paper oil' market indicator [101]. The value of the US Dollar also plays important roles in the world oil price movement [105–108]. Indonesia has very little control for global oil price [109].

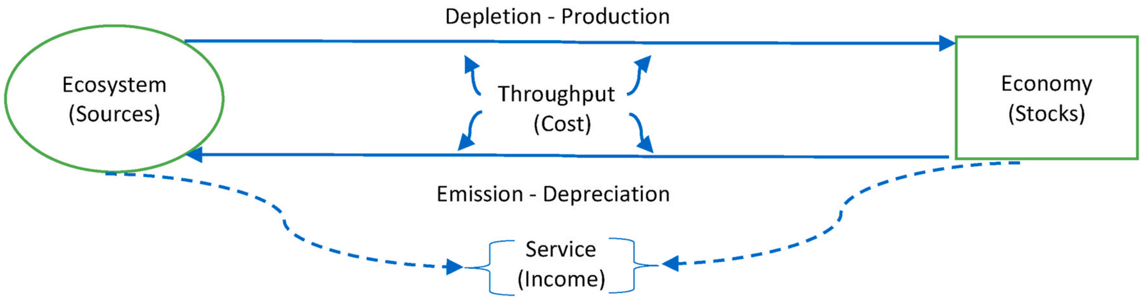

Fig. 1. The energy cycle from a steady-state economy view (source: adapted from Daly [88]).

Table 1
Major oil-related physical and economic, disruptions and climate change concern in recent years.

Year	Movements in oil supply and demand		Movements in climate change agreements
	Disruption	Impact	
2008–2009	Strong demand for oil from China and India, beginning 2000 until 1st semester 2008, followed by the global financial crisis 2008–2009	Oil price rallied from the early 2000s and reached a peak in 1st semester 2008 [110], oil price fell in 2nd semester 2008 and 2009 [111]	
2009			The Copenhagen Accord, dissent between developed and developing countries: aims to limit average temperature rise to 2 °C, failed to achieve the necessary commitments [112]
2011	Libyan civil war	Oil price spike of short term duration [113]	
2nd half 2014–2015	Weak demand, strong supply growth especially from the US, Canada, Libya and Iraq	Oil price falls [111,114]	
2015			Paris Agreement, US notifies its withdrawal from agreement
1st quarter 2020	Saudi Arabia, Russia and US oil price war	Oil price falls [115]	
2020	Covid-19 pandemic	Demand drops, oil prices fall [97,116]	

goals. It manages US$50 billion in pools which support the transition [121]. Given its size in capital markets, the company's lead could prompt American business and other large money managers to follow suit [122]. Some major energy corporations are reconsidering climate change issues in their carbon accounting. Shell aims by 2050 to cut GHGs generated from its products by 'around half' from 2017 levels [123]. Repsol set emission targets to reduce carbon intensity by 3% (2016–2020), with the intention to achieve 40% by 2040 [123]. British Petroleum [124] and Total [125] have announced their commitment to be carbon neutral by 2050.

What is the position of Indonesia amidst the turning geopolitics of oil? Foremost, it is an importer and, as demonstrated below, is likely to remain so. Fortunately for the populace, the rise of the United States as an exporter has escalated competition among the global giants. The world is facing a new oil order, with abundant supply in the next decade [95] (though beyond 2100 it remains in question). This medium term development could have a positive impact on Indonesia in terms of choice of suppliers and moderate pricing. However, the politics of climate change will affect both oil producers and consumers.

4.2. Oil supply logistics in Indonesia

Exploitation of crude oil in Indonesia is long established. Under the Dutch colonial regime, commercial production first occurred in 1885, located in Pangkalan Brandan, North Sumatera [126,127]. During colonialization, which prevailed until after the Second World War (to 1960), several American companies such as Caltex and Standard Vacuum undertook exploration and production [128]. United States multinationals subsequently dominated domestic crude oil production. In 2018, onshore firms contributed less than 40% of such output (from the state-owned company, Pertamina, and a private national company, Medco). In August 2021, Pertamina will take over the oil block from Chevron which has a capacity 207,000 bpd or 26% of domestic oil supply [129]. That move will increase the share of onshore companies to more than 60% of crude supply.

Oil remains dominant in Indonesia's total primary energy structure (TPES). Domestic production decreased gradually at an average of 2.8% p. a. from 2010 to 2018 (Table 2). In electricity generation, the contribution of oil is 7.6%, in third position after coal (58%) and natural gas (22%) [130]. Crude oil production in Indonesia in 2018 was 808,000 bpd, with consumption at 1,785,000 bpd [89]. The difference is made up by imports. Offshore crude is mostly sourced from OPEC members and 70% of oil product imports come from Singapore and Malaysia [131].

Oil consumption rose at an annual average 2.73% p. a. from 2010 to 2018. This trend is expected to persist, since Indonesia has had stable economic growth and has improved its national transportation infrastructure remarkably in recent years. Government support for fossil fuels, partly reflected in a forthcoming boost to refining, indicates that oil consumption will grow to 2040 (Table 2). It is underwritten by steady uptake of gasoline, diesel and jet fuel, in turn reflecting higher incomes and needs for transportation services [130]. State-owned Pertamina accounts for more than 90% of national refinery capacity and fuel distribution in Indonesia [132,133].

Total proven oil reserves in the country were 3.15 billion barrels at the end 2018, and potential reserves are estimated at 4.36 billion barrels [21]. Proven reserves are commonly regarded as the volume of oil that can be exploited under current technologies at economically viable prices [134]. They are labelled 'identified' in the McKelvey [135] classification of mineral resources. The other 4.36 billion barrels [21,136,137] can be seen as hypothetical, undiscovered resources which need exploration to confirm their existence. Given the current rate of production and consumption and assuming no additional new sources, identified oil reserves will suffice until 2030, unless hypothetical resources can be brought on-line. The nation has been dealing with the problems of aging oil fields and little significant investment [43], the latter now a hurdle in pursuing potential sources.

Indonesia relies upon operational oil stocks held by Pertamina, amounting to 22 days' consumption. It does not have a strategic buffer

Table 2
Trend of oil production and consumption in Indonesia 2010–2018 (in thousand bpd) [21,130] and forecasts to 2040 based on data in Presidential Regulation No. 22/2017.

Indicator	2010	2011	2012	2013	2014	2015	2016	2017	2018	2025	2030	2040
Oil Production	1003	952	917	883	847	838	876	838	808	568	677	818
Oil Consumption	1415	1590	1646	1677	1708	1571	1628	1696	1785	2197	2538	2776
Refinery throughput	853	880	820	822	848	836	885	885	916	1734	1734	1734
Refinery capacity	1099	1099	1099	1099	1099	1099	1151	1151	1151	2425	2425	2425

in case of any supply disruption. As against its lack of domestic capacity, it is reported that one-fifth of Singapore's storage is allocated to, but, importantly, is not *owned* by Indonesia [132]. As per internationally-accepted practice, International Energy Agency (IEA) and European Union (EU) members are required to hold emergency oil stocks equivalent to at least 90 days of their net imports [92,138]. For example, China has around 80 days in storage, including volumes in its state strategic petroleum reserve, storage at oil firms and commercial stocks [139].

The evidence from this assessment is broadly that Indonesia's reliance on oil does constitute a problem. Its usage is increasing and will not be met from onshore sources over the long term. The nation relies on friendly countries for refining capacity and, more critically, offshore reserves which are low by advanced international standards. As the economy grows, increasing consumption of oil will do nothing for the country's performance or reputation in international carbon accounting. The future appears at best clouded.

4.3. The government oil subsidy

Indonesia, rich in natural assets, believes that certain types should be regulated and publicly managed. Under the Constitution Article 33, land, water and resources are possessed by the State and used maximally for the wealth of inhabitants. The Article provides guidance for decision-makers to manage operations and supplement free market mechanisms as deemed appropriate. The government has accordingly established state-owned companies to exploit resources. Private enterprises can obtain exploration licenses and pay royalties or a profit share once producing commercially.

The political economy of Indonesia during the last 50 years is over-arched by the legacy of the New Order in providing cheap and affordable energy for the people. Under President Soeharto (1965–1998), the administration subsidized energy consumption. Until 2003 Indonesia had a surplus of oil and enjoyed its position as a global exporter. Prior to that time, the subsidy was not a sensitive problem and was unaffected by international price fluctuations. It continued through the presidencies of Habibie (1998–1999), Abdurrahman Wahid and Megawati (1999–2004), Susilo Bambang Yudhoyono (2004–2014) and Joko Widodo (2014-present). The policy has become regarded as a 'culture' that is both politically and socially acceptable [140]. Effectively, Indonesians have been lulled by cheap energy though, through the lens of political economy, oil should be regarded as a 'scarce resource'.

The impact of the 1998 Asian monetary and financial crisis was felt for more than a decade afterwards.[6] It led to an increase in poverty and significant impairment of purchasing power for millions of citizens. In the regime of Susilo Bambang Yudhoyono, when the economy began to grow consistently by more than 5% annually, policy continued to subsidize oil products and electricity. The impost consumed around 20% of the national budget over 2011–2014. Since 2015, President Joko Widodo has cut the disbursement significantly to around 5% (oil products alone stand at 3%) (Table 3, and Figs. 2 and 3). In contrast to revisions affecting gasoline and diesel, assistance for liquefied petroleum gas (LPG) has been maintained: it is mainly used by the household sector for cooking.

It is well known that ongoing subsidies by sector or product can create significant market or trade distortions [144]. Despite its gradual withdrawal, the oil subsidy poses a major problem for the government's budget. The higher world oil prices climb, the more funds must be allocated. The global price underwent several major rises from 2004 to 2014. In 2008 it soared to almost US$150 a barrel, and in the individual years from 2011 to 2014 achieved US$126, US$128, US$118 and US $115 respectively. The energy subsidy prevents the government from aiding clearly productive sectors. Though characterized as a universal welfare measure, the practice in Indonesia tends to be regressive. The low-income population enjoys only 36% of the benefits and less than 1% find their way to the poorest [145,146]. Several studies argue the need to reduce or remove the aid altogether [91,147–151]. In order to maximize social benefit, a potential mechanism is to shift away from universal assistance based on subsidized fossil fuels towards long-term and targeted welfare programs [152]. The World Bank [153] underlines that such subsidies contribute significantly (13%) to global CO_2 emissions, while failing to help the needy. The subsidy diverts resources from other productive or welfare opportunities and finds little support internationally. Meanwhile, the economic relationship of a public subsidy, which presumably increases demand for oil from state-owned enterprises, remains under-explored in the academic literature.

4.4. Indonesian policy toward GHG emission reduction

Indonesia is recognized as one of the world's largest absolute emitters of CO_2. Output from fossil fuels in 2017 reached 495.9 $mtCO_2e$ (million tons CO_2 equivalent) (Table 4), representing 1.5% of global fossil CO_2 generation [154] and 43% of total Indonesian emissions. Disaggregated, CO_2 output from oil combustion contributed 228 $mtCO_2e$ (Table 4), equal to 19.8% of national emissions, 46% of national fossil-based CO_2 output and 2% of global oil CO_2 combustion.

Indonesia ratified the Paris Agreement through its Law No. 16/2016. The government has stipulated its NDC to be a minimum 29% of the expected total Business as Usual (BaU) level (i.e. 2,034 $mtCO_2e$ in 2030), to which the energy sector contributes 67% or 1,355 $mtCO_2e$ (Table 5). The unconditional reduction target is 11% of the total BaU, while the conditional figure is 14%, that being subject to international support for finance, technology development, and capacity-building (Table 5).

Based on data from the Indonesian Ministry of Environment and Forestry, the level of national emissions from energy in 2018 was 558.89 $mtCO_2e$. By using the historical growth rate of 3.56% p. a. on a BaU straight-line basis, output is projected to be 886.04 $mtCO_2e$ in 2030. Given the unconditional level, the NDC target will be easily achieved if Indonesia maintains its BaU scenario. Since there is no detailed target disaggregated for the energy sector, the reduction needed from each source, such as from coal, oil and gas, cannot be readily assessed. Intuitively, achievement of the NDC might suggest a successful contribution, but its targets are basically inadequate. The nation needs to be more ambitious in reducing its GHGs to counter its current prominence in world emission rankings.

[6] Readers interested in the recovery of the Indonesian economy after the financial crises in the 1990s and 2000s are referered to these sources [141,142]. Based on the experience of the 1997/98 Asian crisis, Indonesia becomes more prudent in response to anticipate succeeding crisis with appropriate measures [142].

Table 3
Trend of the energy subsidy in Indonesia [143] [a].

Year	Oil Products (billion USD)					Electricity subsidy (billion USD)	Energy subsidy (billion USD)	Government expenditure (billion USD)
	Gasoline	Diesel	Kerosene	LPG	Oil products subsidy			
	1	2	3	4	5 = 1 + 2 + 3 + 4	6	7 = 5 + 6	8
2014	9.173	6.302	0.606	4.123	20.204	8.572	28.776	149.620
2015	0.836	1.529	0.024	1.932	4.321	4.356	8.677	134.895
2016	0.090	1.151	0.168	1.874	3.283	4.742	8.025	140.097
2017	–	0.542	0.142	3.270	3.954	3.417	7.371	149.981
2018	–	2.188	0.221	3.851	6.260	3.376	9.636	155.339
2019	–	1.929	0.196	3.828	5.953	3.723	9.676	165.531
2020	Not available	Not available	Not available	Not available	4.900	3.805	8.705	176.417

[a] Data for 2009–2018 are based on audited government financial statements, those for 2019 come from unaudited financial government statements, and data for 2020 are based on the national budget.

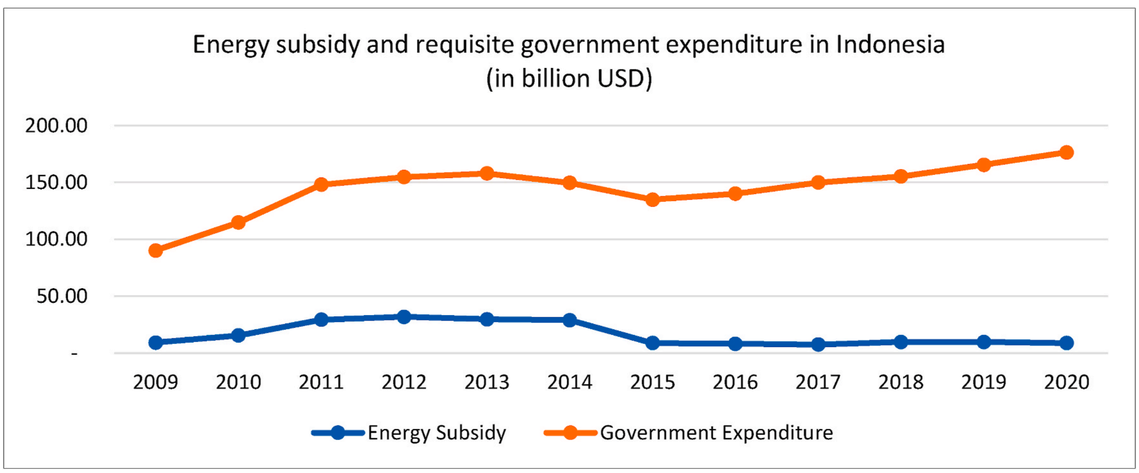

Fig. 2. Energy subsidy in Indonesia [143].

Moreover, the energy policy outlined in RUEN, given its impacts on the environment, is ambivalent. The government realizes the adverse effects of fossil-based fuels but continues to prioritize them in pursuit of economic motives. As per Presidential Regulation No. 5/2006, one of the national objectives is to establish a mix in 2025 in which oil's share would be less than 20%, gas at least 30%, coal at least 33%, biofuel at least 5%, geothermal at least 5%, renewable energy at least 5%, and liquid coal at least 2%. This policy background acknowledges Indonesia's greater dependence on oil imports since 2004. The regulation promotes use of gas and coal which would ease the burden of subsidies on the budget, as well as provide cheaper energy for the economy.

Through Presidential Regulation No. 22/2017, RUEN revises targets for the total primary energy supply (TPES) in the medium and long-terms. Table 6 reveals an ambitious goal for reducing the dependence on oil in the energy mix from around 38.5% today to 25% in 2025 and below 20% in 2050. Though the government plans to raise the role of renewables, it simultaneously aims to increase the share of coal and gas in the Indonesian TPES. In aggregate, fossil-based sources remain strongly endorsed, 77% in 2025 and 69% in 2050.

Renewables' share in TPES climbed slowly from 5% in 2010 [48] to 8% in 2018 [21]. Over the medium-term plan for 2020–2024, Indonesia aims to build power generation infrastructure in which 13.4 GW will rely on coal, 4.6 GW on gas, and 9 GW on renewable energy. The nation encourages the use of coal due to its abundant reserves, which permit overseas sales: it was the world's fourth-ranking exporter in 2019. Compared with other fossil-based sources, coal generates the lowest energy unit per 1,000 tons but emits the most GHGs (Table 7). Though environmentally 'dirty', it is still the most cost-competitive fuel, yet renewables are catching up (Table 8).

4.5. *Progress of renewable energy*

The potential of renewable energy in Indonesia, as identified in Presidential Regulation No. 22/2017, can be seen in Table 9. Current utilization is low. Excluding any construction and/or assembly requirements involving imports, renewable sources are completely secure and not depleting. With such abundant potential, Indonesia has weak justification to favor fossil fuels. The cost of generation via renewable energy has fallen globally over the past decade, driven by improving technologies, economies of scale, increasingly competitive supply chains and expanding supplier experience [163]. For power projects (unassisted by public subsidies), solar photovoltaics (PV) show the sharpest cost decline (82%) over 2010–2019; concentrating solar power fell by 47%, onshore wind by 40%, offshore wind by 29%, and bioenergy by 13% [163]. Renewable energy is becoming more attractive, given the alternative capital expense of new fossil fuel power stations [164]. Indonesia's renewable project costs have followed the trend, gradually closing in on international benchmarks [165].

Despite this new-found competitiveness, neglect of renewable energy relates to a variety of political and economic factors, including lobbying and the use of coal to satisfy increased energy demand [166]. Coal consumption has recently surged, supported by public subsidies and, predictably within a political economy approach, backed by powerful industries [166] including offices of overseas export credit agencies from China, Japan, and South Korea [80]. The falling cost of renewables offers a sound reason why the government should evaluate and

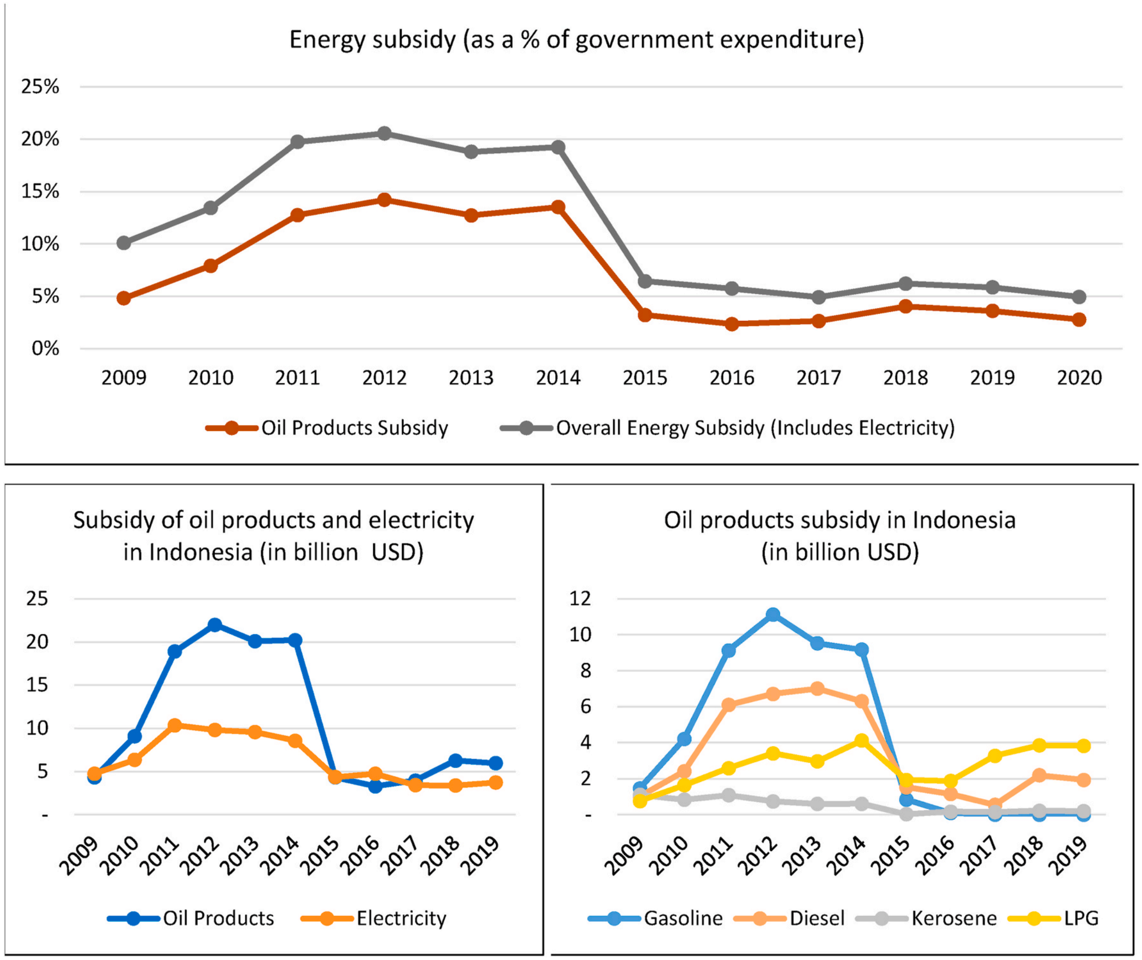

Fig. 3. Energy subsidy in Indonesia 2009–2020 based on components [143].

Table 4
Indonesian GHG emissions from the energy sector in $mtCO_2e$[a].

Year	Oil comb [154]	Gas comb [154]	Coal comb [154]	Fossil-based energy comb [154]	Energy emissions [155]	Total Indonesian emissions [155]	% Oil comb/total Indonesian emissions	World oil comb [154]	% Ind Oil comb/ world Oil comb
a	B	c	d	e = b + c + d	f	g	h = b/f	i	j = b/h
2009	177.4	69.3	113.9	360.6	405.65	1,555.97	11.40%	28,845	1.25%
2010	178.5	71.3	107.9	357.6	453.24	1,116.23	15.99%	30,571	1.17%
2011	210.0	71.6	108.7	390.3	507.36	1,354.62	15.50%	31,393	1.24%
2012	226.7	73.8	114.8	415.2	540.42	1,477.78	15.34%	31,777	1.31%
2013	225.8	76.2	115.9	417.9	496.03	1,349.80	16.73%	32,363	1.29%
2014	229.0	78.1	149.7	456.9	531.14	1,768.21	12.95%	32,439	1.41%
2015	216.3	77.8	165.0	459.1	536.31	2,372.56	9.12%	32,431	1.42%
2016	204.7	75.5	174.1	454.3	538.03	1,457.82	14.04%	32,414	1.40%
2017	228.0	73.5	194.4	495.9	558.89	1,150.77	19.81%	32,840	1.51%

Note: comb = combustion.
[a] Fossil-based CO_2 combustion (oil, gas, coal) and world oil CO_2 combustion data are derived from the IEA, based on calculations for CO_2 combustion only. Energy and total Indonesian emissions data come from the Indonesian Ministry of Environment and Forestry, based on a calculation for CO_2, CH_4 (methane), and N_2O (nitrous oxide) emissions from energy combustion and fugitives (including renewable energy). The Ministry has specified emission data taking a sectoral approach, not one for each type of energy source. It can be assumed that both data publications are interoperable since their calculations rely on the 2006 IPCC guidelines.

re-prioritize its policies. The EU countries have moved from coal to renewable sources in power generation [167,168]. In 2020, the United States for the first time saw renewables surpass coal in its energy uptake [169]. Similarly, China is among the leading countries in terms of the growth rate of renewables [170].

The Indonesian government's apparent bias towards fossil-based energy is further revealed in financial instruments and incentives displayed in Table 10. It recently enacted an Omnibus Law No. 11/2020 on Employment Creation which aims to assist the conduct of business in almost all sectors, including energy, with a view to accelerating upstream investment. The law provides facilitation and centralizes the issuance of licenses from the central government to shorten bureaucratic procedures (formerly, some came from local government). While it emphasizes incentives for oil, gas, coal and geothermal investment, any leaning to renewables (except geothermal) is not specified. Nevertheless, the government is in process of drafting a renewable energy law

Table 5
Targets of the Indonesian NDC [156,157].

No.	Sector	GHG level 2010	GHG level 2030			GHG reduction				Annual average growth BaU 2010–2030	Average growth 2000–2012
		Baseline	BaU	Uncond	Cond	Uncond	Cond	Uncond (% of BaU)	Cond (% of BaU)		
1	Energy	453.2	1,669	1,355	1,271	314	398	11%	14%	6.7%	4.50%
2	Waste	88	296	285	270	11	26	0.38%	1%	6.3%	4.00%
3	IPPU[a]	36	69.6	66.85	66.35	2.75	3.25	0.10%	0.11%	3.4%	0.10%
4	Agriculture	110.5	119.66	110.39	115.86	9	4	0.32%	0.13%	0.4%	1.30%
5	Forestry	647	714	217	64	497	650	17.2%	23%	0.5%	2.70%
	Total	1,334	2,869	2,034	1,787	834	1,081	29%	38%	3.9%	3.20%

Note: cond = conditional, uncond = unconditional.
[a] IPPU is an abbreviation for the industrial processes and product use.

Table 6
Targeted energy mix in the long run as stated in RUEN.

Energy sources	2025 (in %)	2050 (in %)
Renewable energy	>23	>31
Oil	<25	<20
Coal	>30	>25
Gas	>22	>24
Total	**100**	**100**

Table 7
Energy generated and average CO_2 emissions from OECD countries for selected fossil-based combustion [158].

Energy type	Net calorific value (Tera Joule/1000 tons)	CO_2 emission (Kg/Tera Joule)	gCO_2/kWh
Oil and oil products			
Crude oil	42	73,300	600.00
natural gas liquids	44	64,200	Not available
Motor gasoline	44	69,300	Not available
Aviation gasoline	44	70,000	Not available
Jet gasoline	44	70,000	Not available
Jet kerosene	44	71,500	655
Other kerosene	44	71,900	655
Shale oil	38	73,300	1,195
Gas/Diesel oil	43	74,100	700
LPG	47	63,100	540
Residual fuel oil	40	77,400	Not available
Coal			
Anthracite	27	98,300	860
Coking coal	28	94,600	845
Other bituminous coal	26	94,600	870
Sub-bituminous coal	19	96,100	940
Lignite	12	101,000	1,020
Natural gas	48	56,100	400
Biofuel			
Biogasoline	30	70,800	Not available
Biodiesels	27	70,800	Not available
Other liquid biofuels	27	79,600	Not available
Biomass	50	54,600	Not available

which is hoped to provide more stimulus.

Among renewables, authorities have paid particular attention to the substitution of diesel using palm oil. Indonesia is a leader in crude palm oil (CPO) operations, currently accounting for 55% of world output [179]. In 2019, it supplied 48.4 million tons, of which 28.3 million were exported [180] and 6.4 million were absorbed for biodiesel applications [181]. Mass production of biodiesel began in 2014 by way of 'B10', the code denoting the blending of 10% of palm oil with 90% of diesel. The industry successfully implemented B20 from 2016 to 2018, B30 in 2019, and in 2020 was well underway to develop B40.

Table 8
Levelized cost comparison for electricity generation from selected energy sources [159], except for hydropower and biofuels from IRENA [160,161] and diesel from Lazard.com [162].

Sources	USD/kWh		USD/toe[a]	
	Lower	Upper	Lower	Upper
Solar PV- rooftop residential	0.15	0.24	1,756.13	2,814.46
Solar PV- rooftop (commercial and industrial)	0.08	0.15	872.25	1,791.02
Solar PV - community	0.06	0.15	744.32	1,721.24
Solar PV - crystalline utility scale	0.04	0.04	418.68	511.72
Solar PV - thin film utility scale	0.03	0.04	372.16	488.46
Solar thermal tower with storage	0.13	0.16	1,465.38	1,814.28
Hydropower	0.02	0.06	232.60	697.80
Geothermal	0.07	0.11	802.47	1,302.56
Wind	0.03	0.05	325.64	628.02
Coal	0.07	0.15	767.58	1,767.76
Biofuel/Biomass	0.03	0.25	325.64	2,907.65
Diesel	0.20	0.28	2,291.11	3,268.03
Gas peaking	0.15	0.20	1,744.50	2,314.37
Gas combined cycle	0.04	0.07	511.72	790.84
Natural gas reciprocating engine	0.07	0.11	790.84	1,232.78

[a] Converting the cost from kilo watt hour (kWh) to ton oil equivalent (toe), viz. 1 kWh = 8.598×10^{-5} toe [158].

To reach targets in biofuel production, the government provides incentives through Presidential Regulations No. 61/2015 and No. 66/2018. Both facilitate financing derived from a palm oil export levy. The incentive via the CPO fund covers the gap between the market price index of diesel and that of biodiesel.[7] The fund is paid to corporations producing the biodiesel. From 2015 to 2019, the government collected CPO funding of approximately IDR47.28 trillion or USD3.4 billion, which USD2.2 billion has been allocated for biodiesel production support [184]. This policy and its implementation created a lucrative market opportunity for the biodiesel industry [185]. However, only large and cohesive agro-industries and the state-owned company, Pertamina, are able to obtain the benefits [185,186]. Pertamina is authorized by the government to blend the biodiesel for domestic consumption, leading to a mutual symbiosis with the biofuel industry

[7] In 2020, the average market index price for diesel was IDR4,515/litre or US $0.31/litre [182], while that for biodiesel was Rp8,567/litre or US$0.59 [183]. Hence, in 2020, the government allocated the incentive as many as the gap between both market index price i.e. Rp4,052/litre or US$0.28/litre.

Table 9
Renewable energy potentials in Indonesia as stated in Presidential Regulation No. 22/2017 (RUEN).

Energy sources	Potential capacity[a] (Mega Watt)	Installed capacity (Mega Watt)	% utilization of potential capacity	Reliability	Environmental impacts
Geothermal	29,544	1,438.5	4.9%	High	Low
Hydro	75,091	4,826.7	6.4%	High	Low
Mini & micro hydro	19.385	197.4	1.0%	Medium	Low
Biofuel	32,654	1,671.0	5.1%	High	Medium
Solar	207,898	78.5	0.04%	High	Low
Wind	60,647	3.1	0.01%	Low	Low
Waves	17,989	0.3	0.002%	Medium	Low

Note: Reliability and environmental impact are based on authors' assessment.
[a] Total capacity based on all currently known opportunities.

Table 10
Incentives in the Indonesian energy sector.

Type of incentives	Oil and gas	Coal	Renewables	Regulation
Rate decrease for value added tax, sales tax on luxury goods, income tax and property tax [171,172]	Yes			• Law No. 11/2020 11 • Ministry of Finance Regulations No. 122/2019 and No. 67/2020
Free import excise in specific zone [171]	Yes			Law No. 11/2020
Free to choose cost recovery or gross split scheme [173]	Yes			MEMR Regulation No. 12/2020
Free royalty for coal mining and processing in domestic industry [174]		Yes		• Law No. 3/2020 • Law No.11/2020
License is given for integrated coal mining, as long as the life time of the reserves [175]		Yes		• Law No. 3/2020 • Law No. 11/2020
Simplification of business license and permits [176]	Yes	Yes	Yes	Law No. 11/2020
Free added-value tax for LNG selling [177]	Yes			Government Regulation No. 48/2020
Reduction of net taxable income as many as 30% of investment in income tax calculation (terms and conditions applied) [178]	Yes	Yes	Yes	MEMR Regulation No. 16/2015

[185].

Oil is the only form of energy which Indonesia imports: other sources are produced domestically (and even exported in the cases of coal and gas). Imports weaken the control of government over the energy supply. Renewables offer exchange savings via import substitution, avoid international fluctuations, and will enhance the country's capability to provide for its energy needs. Significant replacement opportunities abound (Table 9). The potential shift to very low emission renewables will support global efforts to mitigate climate risks. Cost impacts could be moderated by renewables' increasing availability and economies of scale in production.

5. Discussion

Following the transition from exporting to importing, oil has become a preoccupation of Indonesian energy officials. They are concerned not only about the level of future demand as the country moves toward middle-income status, but also the long-term reliability of supply from on- and offshore sources. The country has coal, but lacks volume in high-quality. With their different material characteristics and end-uses, oil and coal remain imperfect substitutes. More broadly, both these fossil fuels challenge Indonesia's NDC pledge to advance its energy mix towards sustainability and become carbon-neutral by 2050.

Apart from high dependency on oil, the government is relying on historical business as usual practice to manage the energy system. As an immediate repercussion, net oil importation erodes many facets of national security and was the main cause of the deficit in the balance of trade in 2018 and 2019 [187]. By one view, any risk of oil disruption in the international market during the 2020s is subdued: it is predicted that the price will fluctuate only modestly due to plentiful supplies, abetted by the stagnancy of demand.[8] Presently, Indonesia can bide its time and counter insecurity [5–7] by partial substitution for oil with sources to which it has access. Yet, coal, gas and, potentially, biodiesel have adverse impacts in generating high GHG emissions (as shown in Table 7), while the last source also poses problematic land-use issues in the expansion of oil palm plantations [188–190].

Taking the alternative view anticipating significant upsets on the supply side, Indonesia does not have a buffer of oil stocks. It lacks the strategic capacity of developed countries [92,138]. The upside is that this problem can be readily tackled, were the country able to lower its reliance on oil.

The oversized oil subsidy, even though it has been greatly reduced, still accounts for 5% of the national budget. Political and industry support for fossil fuels will probably impede conversion to renewables [42,43], even as the price of the latter becomes more competitive. Certain policy options have been proposed to overcome this impasse [91,147–152]. One of the more important ideas is that the government could redirect the subsidy over the medium term to provide incentives for developing the infrastructure for renewables. This initiative would make them much more attractive compared with fossil fuels and, in turn, will widen and deepen their market, assisting scale economies. Contradictory approaches and unsustainable practice hamper the promotion of renewables. Presidential Regulations No. 22/2017 (RUEN) and No. 5/2006, along with Indonesia's medium term plan for 2020–2024, require reappraisal. Their ambiguity in promoting renewables on one hand, but still favouring coal and gas on the other, reinforces the fossil sources in the long run. Their precedence in the mix is predicted to persist (i.e. remaining at 69% in 2050). This figure questions the government's commitment to advance renewables as well as to achieve the Paris Agreement objectives. We query previous research from Santika, Anisuzzaman [78] and Purwanto, Pratama [55], who argue for the existing coal and gas policy as mentioned in RUEN. Clarifying the regulations is the key concern, if scenario modelling such as that of Kumar [47], Mujiyanto and Tiess [48], Siagian, Yuwono [49], Deendarlianto, Widyaparaga [50] and Daryono, Sugeng [51] around the promotion of renewables is to be realized in the future.

Indonesian performance in 2030 is predicted to be well *below* the

[8] Stagnancy of demand is predicted due to the fall of demand from OECD countries, electric vehicle development prospects, and impacts from Covid-19 pandemic.

level specified in its NDC. This outcome hints at success in public policy, as underlined by Den Elzen, Kuramochi [75] who opine that the country is on track to achieve or overachieve its unconditional targets. We contend, conversely, that the targets exhibit project slack (i.e. are too easily achievable) and need to be revised downwards (to nominate a *lower* level of emission). Another useful move would be for Indonesia to reveal the terms of its commitment towards 'carbon neutrality' over the long term.

Continued BaU adherence in managing the energy system will amplify many of the problems outlined above. Relegating oil and other fossil fuels in favor of renewables will aid both the economy and ecology. The conversion will generate the same amount of income as fossil-based energy in the market but shift its source to renewables. Their monetary development cost is now equivalent to that of fossil fuels [159–163,191] and should fall further over time. The ecological cost to the environment should considerably undercut that of more traditional energy sources.

The problem of conversion turns on the will of the government. Several studies, chiefly in developing countries, argue that the lack of appropriate policies or initiative is a barrier to renewable energy utilization [192–197]. In the years to 2050, a *base*-case scenario would prevail if Indonesia were to retain its current stance. By this reckoning, the share of renewables in the energy mix will slowly increase. Given the historical growth of the sector of three (absolute) percentage points from 2010 to 2018, the proportion could climb to 12% in 2030 and to 20% in 2050. Oil's share would only slightly decrease (from now, 38.8%) because the shift to renewables presumably has a larger impact on coal and gas power plants. In a *best*-case scenario, considering strong development of electric vehicles and power station conversions, renewables could rise to more than 50% of TPES. By using a physical depreciation span of 30 years [198], all fossil-based power plants built before 2020 should become obsolete over 2020–2050 and can potentially be substituted by renewable operations. Maximizing renewable usage would reinforce energy security as defined by Yergin [3].

6. Conclusion

In approaching the question of how Indonesia can plan in the long run for a secure and sustainable energy mix, the current study pursued three project inquiries. As to the first, the prominence of oil in the nation's energy mix can rightly be regarded as a problem, at least on the basis of security and emissions. To answer the second inquiry, such reliance can, in theory, continue so long as a country can afford the pecuniary and non-pecuniary (reputational) costs, but the practicality and desirability of such a course are disputable. Addressing the third inquiry, if oil were to retreat in favor of renewables, Indonesia would obviously encounter short-term expense but also generate longer-term benefits in regard to security, self-reliance, environmental impact and its international standing. Viewed against Daly's [88] consummate equation of ecology and economy, the nation would achieve a significantly more sustainable setting than applies with the present energy mix.

As well as resolving these inquiries, we identified several key findings – shortfalls which hinder Indonesia's progress toward a long term, sustainable energy plan. They consist of: high dependency on fossil fuels and, in particular, oil imports; an oversized oil subsidy; a lack of strategic oil buffers; insufficient attention to emissions; and contradictory policies towards renewable energy. RUEN, something of a 'black box' in respect of academic research and political economy, is insufficiently foresightful and should be modified to enable ongoing reforms. The onshore placement and falling expense of renewables provide good opportunities. Phasing down of fossil fuels need not create undue risk to the balance of the energy system from either a cost or security angle. Conversion also addresses the importance of GHG emissions reduction [199–203].

Future research should probe the mechanics and feasibility of the nation's energy mix and security to 2050. First, dynamic modelling is needed to understand energy system behavior and structural relationships among factors or variables influencing supply. Informing such analysis is the 2015 Paris Agreement. Projection of the mix from both supply and demand viewpoints is required. Modelling can help identify pathways to achieve a sustainable balance between energy security (self-sufficiency), energy equity (cost and benefit) and environmental protection (GHG emissions).

Second, combining project management and strategic planning, scenario analysis is needed to discern the impact of interventions from different stakeholders along the energy supply chain. Several outcomes are expected from a reduced demand for oil, conversion from oil (and also coal and gas) to renewables, adoption of zero emission vehicles and, possibly, battery technology and the onset of carbon capture storage. The Indonesian energy system is mostly centralized: oil, gas and electricity are under the government's control and monopolized by state-owned corporations, so reform could be achievable if the will exists.

Third, supplementary investigation is needed of specific aspects which can provide leverage to enhance the nation's energy mix and security. Public acceptance of novel sources could become an important topic for further analysis of future public policy making. A related aspect could be the extent of existing state control of energy provision, in that many onshore renewable applications can achieve internal economies at a smaller operating scale than large installations such as oil refineries and power plants. In this way, some decentralization and privatization could introduce greater supply competitiveness.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Acknowledgements

We thank anonymous reviewers for their constructive and insightful commentary. We acknowledge the scholarship support to Arief Rahman from the Indonesian Endowment Fund for Education (Lembaga Pengelola Dana Pendidikan - LPDP), Ministry of Finance, Indonesia. Findings and conclusions are those of the authors and do not necessarily reflect the view of the funding agency or any other Indonesian government offices or political organizations.

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