Introduction

Indonesia’s energy needs and policy ambitions

Indonesia’s significant economic growth in the past decade, due to increasing investment and export growth, has been accompanied by increasing energy demand that is met by oil, gas, coal, and renewables (World Bank, 2018; Secretariat General of National Energy Council, 2016: 51). Of these, coal is Indonesia’s most important energy resource for domestic power production and also garners vast export earnings. Nearly 80% of the nation’s coal productions were exported in 2015, making it the largest coal exporter in the world despite possessing only 2.2% of the global coal reserves (Atteridge, Aung, and Nugroho, 2018; BP, 2018; Cornot-Gandolphe, 2017). As a result, the increasing energy demand and consumption have made Indonesia the eighth-largest greenhouse gas (GHG) global emitter (Friedrich, Ge, and Damassa, 2015). In 2012, CO₂ emissions were distributed across three main sectors, with power generation, industry, and transportation accounting for roughly 33%, 30%, and 29% respectively (Republic of Indonesia, 2015).

In 2016, Indonesia introduced its Nationally Determined Contribution (NDC) targets of a 26% and 29% GHG emission reduction by 2020 and 2030 respectively, in comparison to the business-as-usual scenario. However, capacity additions have been in favour of coal and most of the planned renewables come in well after 2020 (Climate Action Tracker, 2018). A high-carbon pathway, evidenced in these energy plans and GHG emission trends, is far from being consistent with NDC targets. Indonesia’s policies are currently rated as ‘highly insufficient’ to meet its NDC targets (Climate Action Tracker, 2018). Like other countries, it faces several challenges to mainstream and integrate climate change into national planning and development processes.

Indonesia’s main strategy for development is formulated in the National Long-Term Development Plan (RPJPN) which is divided into four five-year National Medium-Term Development Plans (RPJMN). The current RPJMN
applies from 2015 up to 2019. One of its aims is to increase the contribution of renewable energy to help move the renewable energy share to 23% of total primary energy supply by 2025 as mentioned in the NDC. Although the target for the national energy exists, there is no clear implementation plan from the government for how the country will meet the goal. Moreover, other policies in the energy sector often run counter to these commitments, suggesting that mainstreaming is challenged by other priorities. For instance, Indonesia has started shifting coal from international markets to meeting domestic energy demand (IEA, 2014). These targets need concerted efforts and strong support from the government to better integrate emissions and renewable energy plans into energy policy frameworks.

Indeed, policy support for fossil fuel undermines meeting both the NDC targets and the SDGs as the fossil-fuel sector plays a prominent role in economic development for Indonesia. Shifting to a more sustainable economic pathway including clean energy production faces many barriers as economic growth is prioritised over other issues. This contradiction is portrayed by the ongoing construction of non-renewable power plants. Over the past five years, coal capacity has increased by around 13.6GW compared to only 1.8GW of renewable energy (Climate Action Tracker, 2018). Furthermore, the new power plants do not use the most modern energy-efficient technologies. The expansion of coal mining also risks the potential lock-in of carbon-intensive infrastructure and financial assets (Atteridge, Aung, and Nugroho, 2018). As one of the world’s largest coal exporters, Indonesia stands to lose much of this revenue when other countries implement their own mitigation measures. Other problems, such as low tax revenue and low commodity prices, combined with complex bureaucratic and transparency issues, also hinder clean energy infrastructure investment (OECD, 2015).

Rethinking renewable energy solutions in Indonesia

Renewable energy solutions, including bioenergy, need to be geographically and culturally appropriate, low-cost clean fuels that meet energy needs and provide co-benefits; they also need to be practically advantageous by offering, for example, simple implementation, good technological availability, and a strong base of experiential knowledge (Blenkinsopp, Coles, and Kirwan, 2013; Brent and Kruger, 2009; Urmee and Md, 2016). Expanding the use of renewable energy sources (RES) is essential to meet future domestic energy demands and to achieve policy targets. In Indonesia, hydro, geothermal, and biomass are among the promising sources to develop further. However, to date the combined installed capacities of these alternatives remains approximately 7.8% of the total optimum capacities (cited in IEA, 2015).

Bioenergy, the initial object of interest in this narrative, offers many options that have not yet been widely used. Furthermore, the greater availability of land, favourable climatic conditions for agriculture, and lower labour costs also support this focus (Widodo and Rahmarestia, 2008). Focusing on biomass, the nation’s bioenergy comes in many forms of value chains, such as
Indonesia

Biomass gasification (Asadullah, 2014), which have been developed so far with the power capacity of 10–100 kW (Sheh and Setiawan, 2013). Additional potential value chains include synthetic gas using pellets from various species of trees and palm-oil solid waste (Kusumaningrum and Munawar, 2014; Siregar et al., 2017) and anaerobic digestion using agricultural and livestock waste. The latter has been considered successfully implemented by a programme called BIRU (see BIRU, 2018).

Biogas as the focus of this chapter, especially when produced through agricultural waste, is one viable alternative since it can be implemented in rural, and sometimes remote, areas where many of Indonesia’s populations reside and make a living in small-scale agriculture. Biogas provides GHG emission mitigation benefits by lessening demand usage of conventional energy. According to an estimation by BIRU, two million small biogas digesters could potentially be installed in Indonesia, being equivalent to a reduction of 6.4 million tons CO₂/year (cited in Devisscher et al., 2017). Meanwhile, the estimated potential capacity for large-scale biogas-to-electricity production is 2.6 GW (Government of Indonesia, 2017). For this reason, biogas pathways are of increasing interest to policymakers because of their carbon and energy benefits and numerous potential co-benefits, such as suppressing unmanaged firewood collection, promoting waste management, and helping with the use of biogas slurry as organic fertiliser (Bedi, Sparrow, & Tasciotti, 2017).

Overall, biogas offers some promising practical and feasible alternative energy options for Indonesia. But how could this technology be rolled out across as ethnically and culturally diverse country as Indonesia, spread across more than 17,000 islands? What about the suitability, the social acceptance, and the gender and equity dimensions of biogas? What do stakeholders see as the main opportunities and risks of biogas, and what can the latest research tell us? This narrative investigates the potential of biogas to help meet domestic energy needs and to comply with Indonesia’s climate mitigation commitments and development planning. At the core are experiences with four biogas programmes taking place in Bali; each having different motivations, practices, outcomes, and lessons. A better comprehension of the risks and uncertainties associated with biogas development pathways can help support future dialogue and planning on climate, energy, and development.

Research process and methods

A range of stakeholder engagement activities were used to understand how stakeholders perceive and manage risks. Risks were discussed during different types of meetings, using different research methods as described in Table 12.1.

Activities included a series of workshops and a period of in-depth fieldwork. The team also conducted continuous dialogues with national-level policymakers to discuss the pathways of choice. The dialogue was a result of a collaboration with the Ministry of Development and Planning (Bappenas), which also involved
the Ministry of Energy and Mineral Resources (ESDM) and Indonesia’s state-owned electricity company (PLN), which runs the nation’s monopoly market in electricity distribution and generates the majority of the country’s electrical power. We made use of the bioenergy workshops to present and gain information about the pathways and conduct research validation. We also involved additional stakeholders, including an NGO called Yayasan Rumah Energi (YRE), sub-national agricultural and energy agency officers, local farmers (users and non-users), researchers from the local university, banks, and business/private sectors.

We initially focused on the small-scale biogas for rural households as the first priority chosen by the participants. Further potential pathways were formulated based on the earlier stage of the research, as well as the economic and political drivers in Indonesia (Devisscher et al., 2017). Later on, interest divided to a large-scale biogas-for-electricity production pathway and this was discussed during the third workshop and policy dialogues. More information about the research methods used, the development of a ‘toolkit’ for data collection and analysis, and the applicable framework for integration of concepts and methods can be found in Devisscher et al. (2017).

Table 12.1 Chronology of events and activities and research methods

<table>
<thead>
<tr>
<th>Event or activity</th>
<th>Stakeholders involved</th>
<th>Methods applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Bioenergy Workshop on ‘Scoping and Envisioning’, Bali, May 2016</td>
<td>Local farmers, NGOs, local and national government officials, research agencies, banks</td>
<td>Multicriteria assessment for priority technology identification for bioenergy, H-form, system mapping</td>
</tr>
<tr>
<td>Field work in Bali and Jakarta, October–November 2016</td>
<td>Local farmers, NGOs, local government officials</td>
<td>Focus group discussions, interviews</td>
</tr>
<tr>
<td>2nd Bioenergy Workshop on ‘Solutions, Business Models and Enabling Conditions’, Bali, May 2017</td>
<td>Local farmers, NGOs, private sectors, local government officials, research agencies</td>
<td>Focus group discussions and exercises for Q-methodology</td>
</tr>
<tr>
<td>Policy dialogues, Jakarta, February–March 2018</td>
<td>Government officials from Bappenas, ESDM, and PLN</td>
<td>Focus group discussions, risk identification and assessment exercise, pathway exercise</td>
</tr>
<tr>
<td>3rd Bioenergy Workshop on ‘Green Business and Synergy Action’, Bali, April 2018</td>
<td>Local farmers, NGOs, local and national government officials, research agencies</td>
<td>Focus group discussions, exercises on two biogas pathways and Q-methodology validation</td>
</tr>
</tbody>
</table>

**Transition pathways**

Focused on finding ways to meet energy needs, NDCs, and development targets, the Indonesia TRANSrisk narrative aims at improving the understanding on how biogas alternatives could effectively contribute to a low-carbon energy transition and what changes are required to achieve it. Bali is the target area
due to its high potential feedstock for bioenergy production, which could support up to 30% of its current power plant capacity (Government of Indonesia, 2017; Kementerian ESDM, 2017). Furthermore, several biogas programmes have operated in Bali, especially at the small-scale level. These programmes were implemented by the Bali Provincial Agricultural Agency (i.e. SIMANTRI programme), the Agency of Public Works, the West Bali National Park, and an NGO called Yayasan Rumah Energi (YRE, i.e. the BIRU programme). All programmes installed individual biogas digesters except SIMANTRI, which carried out communal installations. Also, the government’s programmes went for fully subsidised operations while the BIRU programme used a market-based approach with partial subsidies (Devisscher et al., 2017). The guarantee period of SIMANTRI and Public Works programmes was set to three months, while BIRU’s was up to three years including maintenance services. However, no clear guarantee scheme existed in the West Bali National Park pilot project. Furthermore, the SIMANTRI programme targeted economic development for the farmers’ livelihood, in which biogas was a supporting system of the whole project; and the Public Work’s programme aimed to support the national policy mandate of renewable energy deployment. Both the others aimed at addressing environmental issues including carbon emissions, with the BIRU programme also focused on energy access and West Bali National Park on reducing forest degradation.

The two selected pathways in this chapter explore options for a low-investment/short-term scenario and a high-investment/long-term scenario. The first is an easily implementable, low-cost household-scale biogas digester system supplying household energy needs. This pathway also foresees the transfer of these systems and the know-how to other geographical areas. The second pathway focuses on large-scale biogas systems that produce electricity, require higher investment, and generate high benefits in the long run. The first pathway uses experiences by farmers (biogas adopters) in Bali, while the second one was developed in discussions with policymaker experts from Bappenas (Ministry of National Development Planning), PLN (Electricity Company), and ESDM (Ministry of Energy and Mineral Resources).

**Household biogas transition pathway**

The household biogas transition pathway is concerned with meeting domestic energy needs for cooking and lighting, which also intersects with issues of health in rural areas, community social structure, as well as smallholder productivity. These issues are important for understanding the pathway.

Nearly one-third of Indonesia’s working population consists of farmers in rural areas (BPS, 2017) where solid fuels are mostly used for cooking and are often associated with health problems (Gall et al., 2013). Indoor pollution in the home from solid fuels utilisation contributes to respiratory infections and diseases. Biogas for household cooking and lighting is clean and safe while also fitting the profile of the rural areas. It can also provide fuel for cooking, give the
benefit of waste management, reduce the indoor pollution risk, produce biogas slurry for organic fertiliser, and even provide lighting where possible.

With low population density in Indonesian rural areas, a household-level or individual system to provide fuel for cooking and lighting could potentially be a better option than a centralised or communal system that requires greater material input as well as management co-ordination. Moreover, an individual system could be deployed without having to formulate a gas (or electricity) distribution system plan within the community, thus potentially reducing the amount of investment.

In addition, biogas offers a potential means to increase farmers’ resilience by, for instance, the use of biogas slurry as organic fertiliser. These could generate new sources of supplementary or additional income for the smallholder, who may trade organic coffee beans with organic fertiliser made on the premises. These benefits to the smallholder farmers should be added to the savings made from reducing the reliance on fossil-fuel-based energy. Additionally, if the government decided to suppress the liquid petroleum gas (LPG) subsidy, those savings will be further increased. These potential benefits add value to the pathway, not only to help the country achieve its NDC target by reducing rural households’ fossil-fuel consumption but also to increase people’s resilience.

**Large-scale biogas-for-electricity transition pathway**

The large-scale biogas transition pathway is mainly concerned with meeting renewable energy and carbon emission targets, as well as a means of addressing the development goal of providing electricity access in remote areas. It has economic potential for the creation of small energy-generating enterprises.

Since 2014, the government of Indonesia has focused on increasing electricity access to rural areas, including remote islands. As it stands, Indonesia has achieved above 94% of its electrification ratio target of 92.75% in 2017 through the Energy-saving Solar-powered Lighting Supply (LTSHE) programme in rural areas (Kementerian ESDM, 2017), although doubts remain over the sustainability of the programme. However, and in contrast, the majority of Indonesia’s current and planned power plants are coal-powered generators. A new approach to investment in electricity generation that has longer-term objectives of supporting low-carbon development may be needed. Currently, one of the most notable initiatives comes from PLN which, under ESDM policy, is opening its doors to private companies by purchasing their services to operate in different areas to generate and sell electricity.

Responding to this policy, many private sector actors are working on renewable energy initiatives but they are less active in biogas-to-electricity enterprises. Stakeholder dialogues elaborated that the current policy is not totally supportive of electricity generation from the RES due to their higher initial and operating costs, especially from biomass. Thus, companies selling electricity generated by biogas will face challenges when competing with the existing electricity price set by the government. There was, however, growing political support to
improve the policy, such as by planning for electricity production using renewable energy and strengthening the feed-in tariff implementation.

Currently, biogas plants are utilised in some areas of Indonesia that are claimed to have performed successfully both as waste management reactors and energy generators. Based on these experiences, the government representatives acknowledged that an approach to increase the number of larger communal biogas plants to produce electricity would be beneficial. They indicated that large biogas plants could potentially support electricity accessibility, apart from its main goal of reducing the emissions from the power generation sector.

Risks and uncertainties associated with biogas development in Indonesia

It is important to first note the subjective nature of risk perception. How risk is experienced and understood encompasses personal arguments of possible events and their consequences (Aven, 2012). What may pose a risk for one group of stakeholders may be totally satisfactory and unproblematic to another. For example, government researchers identified unfiltered H₂S (hydrogen sulphide) in biogas installations as a potential danger, while farmers did not recognise it as a risk due to their different concerns and the lack of knowledge about such facts.

To mitigate some subjectivity, this narrative utilises a widely understood and shared category-based risk assessment to summarise and convey risks. Fourteen risks were identified and formulated into six risk categories (Table 12.2). From this, it is clear that the highest number of risks are associated with technological

Table 12.2 Classified risk perceptions

<table>
<thead>
<tr>
<th>Social</th>
<th>Technological</th>
<th>Economic</th>
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<tbody>
<tr>
<td>1 Collective management issues in the case of larger biogas systems</td>
<td>3 Accessibility and sustainability of feedstock</td>
<td>7 Lack of long-term incentives to aim for value-added activities</td>
</tr>
<tr>
<td>2 Imbalance time spent between men and women</td>
<td>4 Poor maintenance and infrastructure</td>
<td>8 Subsidy on fossil fuels</td>
</tr>
<tr>
<td></td>
<td>5 Unfitting technology choice for local conditions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Leakage of methane gas emissions</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Political</th>
<th>Regulatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Unfiltered hydrogen sulphide in biogas installations</td>
<td>10 Different goals on biogas installations</td>
<td>13 Lengthy and bureaucratic process to apply for support form biogas programmes</td>
</tr>
<tr>
<td></td>
<td>11 Varied monitoring practices in different programmes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 Initial investment needs</td>
<td></td>
</tr>
</tbody>
</table>
aspects such as feedstock, infrastructure, and electricity reliability. These risks will later be introduced as implementation risks, also understood as barriers, and consequential risks, also understood as negative outcomes (Figure 12.1). All policy decisions and actions carry some potential risks that need to be considered in the context of multiple uncertainties.

**Uncertainties in the development of biogas as a renewable energy option**

Four key uncertainties underlying the energy transition to biogas were identified: (i) the unclear role of public and private sectors; (ii) the changing focus over each political term; (iii) the unspecified national biogas target; and (iv) different views on biogas development. Otherwise understood as ‘epistemic uncertainty’, the first three risks are a result of incomplete or insufficient knowledge of the system, while the fourth one is rather classified as an ‘ambiguity’ due to the existence of multiple knowledge frames.

First, the blurred lines between the roles of public and private sectors are responsible for a situation where overlapping and even contrasting context and goals of biogas development exist. This undermines the ability of all actors involved to form innovative partnerships, intensify engagement, or effectively collaborate on programmes. Second, the end of each political term in Indonesia creates a significant uncertainty as there is an absence of knowledge whether the new government will continue or abandon previous/existing programmes. Both of these uncertainties are compounded by a third uncertainty: the lack of biogas development targets. This lack of leadership from the government affects commitments to biogas development by the civil service and the private sectors. If the national biogas target was set, it would motivate ministries and other actors to better co-ordinate biogas programmes to pursue a common objective (Devisscher et al., 2017). Fourth, we found three different perspectives or ‘worldviews’ on the development and value of biogas. They include a technological-based paradigm in addressing barriers, a scale-based paradigm that put forward the agricultural benefits, and independence prioritisation through biogas. The lack of consensus and differences in viewpoints, framings, and perspectives may be implicit or tacit, thus adding additional layers of uncertainty. This uncertainty is present in the different objectives of biogas programmes in Bali, for example the BIRU programme that undertook market-based approach that emphasised technological services and the SIMANTRI programme that put forward the sustainable agriculture and economic profit approach.

Out of the four sources of uncertainty, three stem from the influence of government. The fourth source of uncertainty is a consequence of institutional complexity and the diversity of actors and their experiences and priorities. Investigating this complexity can nonetheless reveal important patterns, such as distinctive views on biogas development and the ways in which different constellations of actors line up behind these perspectives.
Consequential risks

Most significant risks

Implementation risks

• Unset biogas national target
• Methane leakage
• Increased electricity tariff
• Imbalance between men and women
• Technology choice does not fit the local conditions
• Leakage of methane emissions
• Unfiltered hydrogen sulphide (H₂S) in biogas installations

Uncertainties

Biogas development

• Different goals on biogas installations
• Varied monitoring practices in different programmes
• Initial investment needs
• Collective management issues in the case of larger biogas systems
• Accessibility and sustainability of feedstock
• Poor maintenance and infrastructure
• Subsidy on fossil fuels

Figure 12.1 Main uncertainties, implementation, and consequential risks associated with biogas development in Indonesia.
These findings illustrate the possible barriers that policy actors and development planners need to be aware of and sensitive to when designing biogas programmes. To be acceptable to stakeholders with a plurality of perspectives, plans need to include different ways of providing benefits and incentives that motivate participants, while mitigating the perceived drawbacks.

**Implementation risks of biogas development in Indonesia**

Different motivations as a result of different ‘worldviews’ of biogas development were fundamental causes of further incoherence in the monitoring processes, there being no overall consensus on biogas monitoring procedures. We revealed that most of the rural biogas digesters had been abandoned due to the lack of investment in monitoring and evaluation (Devisscher et al., 2017). Monitoring practices are required to assess the current situation of the programmes in order to ensure their sustainability and to help identify technical issues, one of which includes proper infrastructure maintenance. However, appropriate maintenance is lacking in the government-led programmes, which is identified as another risk. When farmers faced constraints in operating biogas or suffered faults in the technology, they gave up using it, especially in the cases where they had no warranty and were not technically trained (Devisscher et al., 2017). Moreover, highly subsidised digesters with little investment in maintenance and monitoring were less successful due to a lower sense of ownership of the biogas digester and a trade-off with the maintenance cost. The representative of ESDM stated that the adequacy and reliability of the overall technological infrastructure should be able to reduce the risks where maintenance is lacking.

In addition, the government-run programmes also presented a barrier in terms of the biogas technology distribution to beneficiaries. The farmers as the targeted beneficiaries stated that the process of obtaining a biogas digester was overly bureaucratic and time consuming (Devisscher et al., 2017). In other words, there are various stages farmers need to undergo to obtain the digesters and, even when offered with no costs, this acts to prevent the farmers from adopting and fully utilising the technology.

Furthermore, accessibility to feedstock was also considered to be a barrier by both users and policymakers (Devisscher et al., 2017). This risk is worth being discussed because, as repeatedly emphasised, the abundance of feedstock is often given as a main justification for biogas development. Yet the farmers reported feedstock shortages, besides considering the collection process as time consuming. The barrier concerning the feedstock availability is also noticed by the ESDM representatives with a similar reason; thus they recommended a system to ensure the feedstock sustainability.

Some risks specifically relate to communal biogas installations. In the SIMANTRI programme, barriers arising include management issues of the digesters (Devisscher et al., 2017). Unsuitable and ineffective management will create risks in biogas deployment since in many cases the farmers did not seem to be committed to managing the biogas as a team. This appears to be correlated
with the lack of familiarity with and sense of belonging to a relatively new technology. Another contributing factor to limited use of communal biogas systems was the location of digesters, which is often far from the communities. A consequence is that they only use biogas for shared needs such as water heating for drinking during community meetings, but not to benefit from cooking in their households.

Finally, a further barrier was suggested to stem from the lack of long-term incentives to engage in household biogas. Some stakeholders, especially policymakers, perceived the need for biogas adoption to go beyond ‘cooking only’ and rather to target value-adding activities to keep farmers engaged in the long run. This sentiment is related to the ‘outsizing’ pathway suggested in terms of co-benefits generated that can become increasingly attractive in the longer term; the policymakers questioned the potential of household biogas to deliver these benefits.

The high initial investment cost is a further barrier or implementation risk, according to the representative of Bappenas. Whether sufficient government funding is available to meet the investment costs for renewable energy is dependent on the political situation. However, the future situation and its impact on investment are far from predictable. This type of investment relies on clear renewable energy targets, an appropriate policy framework, and strong and clear co-operation between public and private actors, where each actor plays its own key roles (Masini and Menichetti, 2012). In this case, the role of policymakers is to create incentives in order to achieve effective investment (IEA, 2007), while the private sector is expected to buffer the financial requirement towards the low-carbon economy (Masini and Menichetti, 2012). However, while the roles of the public and private sectors are either overlapping or leaving gaps, the investment risk remains higher. The risk on the initial investment is thus closely related to the three identified uncertainties that stem from the government influence.

The representatives of ESDM, Bappenas, and PLN stated their specific interest in larger-scale biogas and electricity generation. However, the government and the electricity companies have made limited advances in generating electricity from biogas. Concerns over technology development and infrastructure included the limited capacity of biogas-to-electricity plants to generate energy and electricity tariffs. The representative of PLN was concerned about whether or not electricity generation would be as sustainable in terms of continuity of feedstock supply. This needs to be ensured before buying the electricity from the providers, especially when entering into a long-term contract or partnership. Feed-in tariff schemes could play a critical role in this regard. Also, a PLN representative suggested that if the regulations were weak and technology remained inadequately developed, then production costs would continue to be too high for wide market penetration. The high associated production cost may also result in a higher electricity tariff and thereby be passed on to the end users. Under this scenario, electrification in remote areas would become very difficult to achieve.
Fossil-fuel subsidies present another challenge because they work against biogas development. Challenges posed are fossil fuels being more affordable compared to renewable energy systems. As stated by the Bappenas representatives, farmers, local businesses, and policymakers alike are more likely to favour fossil fuels. Nevertheless, in many rural or isolated areas subsidised fuels are not accessible or rarely available, causing the price to constantly fluctuate.

**Consequential risks of biogas development in Indonesia**

Environmental aspects were a central concern among the consequential risks. For example, some rural biogas digesters were not installed with H$_2$S filtering, which may harm the environment or even human and livestock health according to researchers in Udayana University (Devischer et al., 2017). It also runs the risk of corrosion to the digesters (Chaiprapat et al., 2011). Large quantities of manure in the biodigester may release this gas, unless it is fitted with filtering technology. Unfortunately, in many cases the observed biogas digesters were not equipped with this technology.

Similarly, some methane leakages in the biogas digesters might occur when users do not burn the biogas produced. There have been some debates on whether or not the methane leakage is less harmful to the atmosphere than abandoning the manure on the ground or in the barns. Bruun et al. (2014) argued that a small amount of methane leakage could offset the emissions savings from faulty or improperly used digesters. Also, from the perspective of technological efficiency, biogas technology should be used as optimally as possible in order to take advantage of the feedstock and to reduce the overall GHG emission.

Besides the environmental risks, we identified a specific consequential risk within the social domain. The women in rural Bali tend to have significant roles in collecting the firewood and providing meals, while men’s roles are mainly taking care of livestock and managing organic waste as feedstock for biogas technology. Substitution of biogas for firewood therefore has the effect of reducing the women’s working time while increasing the men’s. Such a role reversal has a positive aspect because women and their families can benefit from women spending more time doing other things. However, it was also recognised that this carries a risk of imbalance and turmoil in the household. Some debates arose around this perception as it is mostly a viewpoint of male farmers, while other stakeholders, such as the policymakers and some researchers, do not view it as a significant issue, suggesting it does not represent the entire situation in Indonesia. Yet such gender-based role division is embedded in many customs across Indonesia.

Despite interesting discussions on the gender role, the representative of PLN seemed to be more concerned about the other pathway, especially the reliability of electricity generation. Conditions may induce a risk to system stability within the interconnection grid. The current state of biogas production tends to fluctuate, which may disturb the current system. To resolve this, the PLN representative
Collective management issues in the case of a larger biogas system
Accessibility and sustainability of feedstock
Poor maintenance and infrastructure
Shifting on household gender division of labour
Varied monitoring practices in different programmes
Lack of long-term incentives for biogas use

Initial investment needs
Unsuitable technology choice for local conditions
Unfiltered hydrogen sulphide (H₂S) in biogas installations
Methane leakage
Subsidy on fossil fuels
Increased electricity tariff
Reliability on electricity generation

Small-scale household biogas
Large-scale biogas for electricity

Figure 12.2 Risks on both pathways: household biogas and large-scale biogas for electricity.

recommended three potential solutions: (i) utilisation of a smart grid; (ii) a co-generation/hybrid system; and (iii) the biogas system for off-grid or isolated areas.

Comparison of pathways

Both pathways aim to assist the government of Indonesia in meeting its emission reduction targets while providing energy access. Against these targets, this section will apply a cross-analysis by classifying each risk under each pathway. The interest in risks on the biogas-to-electricity pathway were stated by the policymakers after the detailed investigation on the household biogas had been delivered to them. Therefore, the risks on large-scale biogas were not identified in depth. Nevertheless, we obtained at least higher-level perceptions on this pathway. The risks from both pathways were either identified as exclusive or overlapping to each other (Figure 12.2).

Risks associated with both pathways

Chief among the risks associated with both pathways is the high initial investment needs (Figure 12.2). This was particularly on the minds of policymaker stakeholders. A representative of Bappenas suggested that the investment cost is a risk to both the small-scale household pathway or the large-scale electrification pathway as limited financial or monetary reliability (with the possibility of
a budget constraint being subsequently imposed) will create obstacles for the overarching development. The lack of investment is likely to create a domino effect on supporting measures such as installation, maintenance, training, and incentives. The risk is identified in both pathways and heavily depends on the national policy on renewable energy. Initial investment is also shaped by enabling policies and regulations concerning the private sector. For example, the latest electricity law (UU no. 30/2009) and its implementing regulation (PP No. 14/2012) allowed the private sectors to be actively involved in the power sector, such as by running a power generation business (Kuvarakul et al., 2014). Suitable laws and regulations would mitigate this risk by attracting more private-sector investment in either pathway, thereby financially supporting the low-carbon economy, as suggested previously (Masini and Menichetti, 2012).

Other important risks are related to how the comparative advantages of the main alternative energy options stack up. In this respect, one of the main challenges is the cheaper fossil-fuel energy. For example, a three-kilogram LPG tank for households is subsidised, as regulated in ESDM’s ministerial decree no. 2458 K/12/MEM/2017. The effect of such subsidy should not be underestimated as, for many rural residents that use LPG, there is a risk of preferring LPG to biogas in this pathway. The main causes are cheaper conventional energy with lower initial investment at the household level, as well as fewer technological barriers. When it comes electricity generation, PLN also faces challenges in purchasing the renewables in general since they are more costly than coal, which is subsidised by the government (International Institute for Sustainable Development, 2018). This subsidy itself is one of the rooted reasonings behind the more affordable current electricity tariff.

Other risks relevant to both pathways concern the choice of technology, which is not always appropriate. For instance, it was noted that in some cases household biogas installations had developed cracks or leaks in the tanks due to unsuitable local biophysical conditions (Devischer et al., 2017). Taking into account the local conditions is a necessity according to the policymakers who emphasised that not all Indonesian regions are suitable for biogas. Bappenas gave the example of Nusa Tenggara Timur (NTT) province – a semi-arid area where biogas development would be difficult, since continuous water supply is essential to operate the technology. On the other hand, the island of Sumatra, one of the world’s largest palm-oil producers, would make a promising biogas generator (Rahayu et al., 2015). The abundance of palm-oil mill effluent (POME) waste and the local conditions may favour choosing technologies for electricity generation from biogas.

We found that risks of possible leakage of methane emissions and unfiltered H₂S would occur on both pathways, as they are based on similar technological principles. Both risks were observed in the household biogas digesters (Devischer et al., 2017) and large-scale ones, such as the POME installations (Promnuan and O-Thong, 2017).
Risks associated only with household-level biogas

Risks associated to household biogas are different from the large scale for electricity, which will be explored in this section. For example, the barriers of collective biogas management at the community level would be unlikely to factor in the large-scale biogas-for-electricity pathway, since the plants would be run as a larger-scale operation with suitable management mechanisms and practices. Similarly, household-level gender discrepancy relates to unpaid work on the smallholding, and likewise, accessibility of the feedstock relates to shortages in the quantity of feedstock for household biogas.

Other risks in the household biogas pathway result mainly from the way the biogas distribution schemes have been designed and implemented. These risks include poor maintenance and infrastructure as well as bureaucratic issues among the potential beneficiaries. The lack of support for maintenance of household systems prevents the rural users from fully benefiting from their biogas installation. According to Berhe et al. (2017), the successful utilisation and maintenance of biogas infrastructure is commonly the joint responsibility of the owner and technical personnel. Clearly, when the capacity of the farmer (financial, skills, knowledge, etc.) is lower, the likelihood of this risk is higher. Increasing the capacity of these actors is necessary for mitigating the risks associated with poor maintenance and infrastructure.

Additionally, there are a number of risks on this pathway that may trigger the users to immediately revert back to conventional energy. For example, when biogas collective management is not well organised, it will create a higher likelihood of the users to seeking easily accessed firewood or even LPG. This is similar to other risks, such as poor maintenance, bureaucratic issues, inadequate incentives, and gender issues: where the farmers face limited options of biogas usage, there is a higher chance for them to seek a more familiar energy option.

Risks associated only with biogas-for-electricity generation

Risks exclusively attached to the biogas-for-electricity pathway concern the reliability of the electricity generation, as well as the increased electricity tariff, both of which were suggested by PLN. PLN actually purchased 1 MW of POME-based electricity in 2015 to distribute it through on-grid channels (Pasadena Engineering Indonesia, 2014). PLN was concerned about whether or not the electricity delivered to the consumers would be as stable as the existing commercial electricity generators (hydroelectricity, thermal, diesel, gas, and geothermal power). Moreover, the quality and quantity of POME could also have implications for the methane proportion in biogas (Yacob et al., 2006). While the common efficiency of natural gas-generated electricity ranges around 38–42% (Breeze, 2014), biogas-generated electrical efficiency ranges between 28% and 40% (Firdaus et al., 2017; Shi, 2011). Second, it was thought that the high operational costs would also contribute to the risks of on-grid electricity.
This might create difficulties in raising finances and it may also necessitate a higher tariff that could be damaging for consumer demand.

Overall, there were higher proportions of discussions on the risks related to household biogas than large-scale electrification, as household biogas was the starting point of the Indonesia narrative. For Bappenas, PLN, and MEMR, being the most familiar with the pathway of large-scale biogas for electricity, there was a knowledge discrepancy during the stakeholder dialogues, leading to a tendency to discuss this pathway less. This situation led stakeholders to focus more on the household biogas pathway. If the risks of the electrification pathway are less well understood, they may also have been underestimated here. In addition, differences in ‘worldviews’ as a part of the uncertainties centred on issues related to biogas installations at household and communal levels. There did not appear to be a lack of consensus around biogas for electrification that resulted in ambiguity and contributed to uncertainty. Stakeholders all thought that producing electricity from animal waste will increase electricity access in remote Indonesian islands, but all disagreed that upscaling biogas for village-wide power generation or commercial scale generation is realistic.

Conclusions

This research identified two pathways of biogas development to reduce emissions and to supply energy needs that could be potentially relevant in Indonesia, namely household biogas and large-scale biogas-for-electricity development pathways. Four sources of uncertainty were salient: (i) the unclear role of public and private sectors; (ii) the changing focus on each political term; (iii) lack of a national biogas target; and (iv) differences of perceptions among the stakeholders. These uncertainties give context to the risks perceived by stakeholders.

Of the risks identified, a higher number were classified as technological risks. The stakeholders tended to focus on the implementation risks (i.e. barriers) rather than the consequential risks (negative outcomes). Moreover, most agree that biogas development has not yet become a government priority. As a result, biogas is not being developed evenly across the country. This situation created a tendency to highlight and criticise current efforts in terms of the barriers experienced.

A comparison of pathways was conducted to increase awareness about what kind of risks to expect, and what kind of uncertainties might interact with and exacerbate these risks. Interestingly, both pathways include some common or similar risks, among them the suitability of technological choices, the possible technological constraints, and the cost of initial investment. Other risks exclusively pertained to one pathway or another. However, further studies on the electricity pathway are needed to identify a wider range of risk perceptions. The severity (potential impact) of each risk is not studied in this narrative.

The risks of the household biogas pathway may lead to difficulties for rural residents to continue using biogas, thus may result in unattainable renewable
energy targets and prevent potential co-benefits such as protecting the environment and improving human health. On the other hand, the biogas-to-electricity pathway risks could create negative impacts on the economy, either commercially (on the market) or at the macro/national level. Therefore, to achieve the national target through these pathways, it is important to suppress the uncertainties at the higher level, or those mainly related to the governance scope, which could include, for example, making progress in formulating targets complemented with clear pathways and providing clarity in how biogas development should be perceived, valued, and approached. It is also recommended that policymakers implement supporting actions to mitigate risks, such as strengthening the institutions that manage the national biogas development.

References


