Attracting private investments into rural electrification — A case study on renewable energy based village grids in Indonesia

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ABSTRACT

Renewable energy based village grids (RVGs) are widely considered to be a sustainable solution for rural electrification in non-OECD countries. However, diffusion rates of RVGs are relatively low. We take the viewpoint that, as public resources are scarce, investments from the private sector are essential to scale-up the diffusion. While existing literature mostly focuses on engineering, development and techno-economic aspects, the private sector's perspective remains under-researched. As investment decisions by private investors are mainly based on the risk/return profile of potential projects we — based on literature reviews and field research — investigate the risk and the return aspects of RVGs in Indonesia, a country with one of the largest potentials for RVGs. We find that considering the potential of local, national and international revenue streams, the returns of RVGs can be positive. Regarding the risk aspect, we see that private investors could address many of the existing barriers through their business model. However, the findings also point to the need for government action in order to further improve the risk/return profile and thereby attract private investments for RVGs.

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Introduction

Today, about 19% of the global population remains without access to electricity (OECD/IEA, 2011). Access to electricity heavily correlates with economic development, and those people lacking access primarily live in rural areas of non-OECD countries (OECD/IEA, 2011). Providing these rural poor with electricity is a major challenge. The amount of additional electricity generation capacity needed is enormous when aiming to stimulate rural development (Bardouille et al., 2012; Cook, 2011; ESMAP, 2008). At the same time, climate change (being a major threat mainly to the poorest countries) needs to be addressed by decoupling electricity production from CO_2 emissions (Bhattacharyya, 2011; Gallagher et al., 2006; Glemarec et al., 2012; UN AGECC, 2010). Grid extension — the conventional solution for electrification in most countries — is often not feasible or too expensive, especially in very remote areas such as islands as is the case in Indonesia (Blum et al., 2013; Deichmann et al., 2011; Rickerson et al., 2012). In such cases, off-grid renewable energy technologies which produce electricity with a very low climate impact and that fit the requirements of a decentralized context, can well address the challenge of low-carbon electrification (Holland and Derbyshire, 2009; Sovacool and Valentine, 2011; Zerriffi, 2011). In 2011, the Journal *Energy for Sustainable Development* published a special issue on off-grid electrification in non-OECD countries, which discussed rural electrification through renewable energy in a series of sixteen articles and was specifically valuable for our study (for an overview see Bhattacharyya, 2011). Several authors from this special issue (e.g., Bhattacharyya, 2011; Schäfer et al., 2011) as well as other researchers (e.g., Glemarec, 2012; Zerriffi, 2011) recommend further research with regard to scaling up diffusion through private investments. Even though research on rural electrification through renewable energy is increasing, most studies address the engineering, development and techno-economic aspects. The private sector's investment decisions, remain poorly researched (Bhattacharyya, 2011, 2012; Kaundinya et al., 2009).

Renewable energy based rural electrification options are diverse and vary greatly regarding the amount of provided electricity and consequently the potential for allowing for the productive use of electricity. While solar lanterns and household-based stand alone systems such as solar home systems offer lighting and limited access to electricity for household purposes, respectively, their contribution to the productive use of electricity is low (Macharia et al., 2010; Ölz and Beerepoot, 2010). Village grids[1] are widely regarded as more promising in terms of a developmental impact because they allow for the productive use of the generated electricity (Cook, 2011; Kanagawa and Nakata, 2007; Legros et al., 2009; Takada and Charles, 2007). If designed well they can, in terms of reliability, outperform the often unstable national grids in non-OECD countries (Peskett, 2011; Yadoo and Cruickshank, 2012). If village grids are powered by renewable

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[1] Village grids, also referred to as micro- or mini-grids, "provide centralized generation at a local level. They operate at a village or district network level, with loads of up to 500 kW" (OECD/IEA, 2011, p. 16) and connect a few up to several thousand households (Bardouille et al., 2012).

energy they not only address the poverty, but also the climate change challenge. While the global market for off-grid solutions bringing modern energy to the rural poor has a size of about 35 billion USD p.a., the market potential for RVGs alone is estimated at an annual 4–5 billion USD (2012) (or about 28 million households) and growing by 13% p.a. (Bardouille et al., 2012; Dean et al., 2012). However, despite the advantages of RVGs, the existence of pilot projects (e.g., in Bolivia, Cambodia, India, Indonesia, Nepal, Nigeria, or the Philippines) and the heavy promotion by development agencies, large-scale diffusion has not yet taken place (Bardouille et al., 2012; Roland and Glania, 2011). In this study we focus on RVGs in Indonesia where they are a very suitable form of rural electrification for three reasons[2] (see also the Background on Indonesia's electricity sector, rural electrification and RVGs section). First, the government of Indonesia (GoI) aims to increase the electrification rate from the current 65–70% to beyond 90% by the end of the decade (PT Perusahaan Listrik Negara, 2010; PWC, 2011; Winoto et al., 2012). Second, Indonesia is an island state, making grid extension complicated and expensive. Third, the country has more than sufficient renewable energy resources, e.g., in forms of solar and hydro power. Theoretically, there are three known sources of finance for RVG projects in Indonesia: first, international grants from non-governmental organizations (NGOs) and developmental agencies providing initial capital for RVG projects,[3] second, grants for electrification provided by the federal GoI (Ministry of Energy and Mineral Resources of Indonesia, 2009), and third, private investors (typically local or regional businesses) and village communities which arrange joint financing agreements. Despite these potential sources of finance, little investments have taken place (Bardouille et al., 2012; OECD/IEA, 2011; PWC, 2011). While the first two sources of capital are limited by the specific grants, the private capital is abundant. In order to understand private investment — or the lack thereof — the risk/return profile is essential, as for private financiers/investors, "the risk–return profile of a project is the ultimate determinant of whether to finance or not" (UNEP, 2012, p. 9).

In this paper, we therefore address the question "*what do the current risk/return profiles of RVGs in Indonesia look like and how can they be improved in order to attract private investments*?" We proceed in two steps. First, we investigate the potential returns of different RVG types by comparing costs with revenues. Second, we turn to risks, by analyzing the barriers that drive investment risks (compare Waissbein et al., 2013) and show how investors could make these risks manageable. Both, positive returns as well as manageable risks are prerequisites for attracting private capital (Glemarec, 2012; UNEP, 2012; Waissbein et al., 2013). The role of the government in supporting the formation of such a favorable environment for investment is essential (The World Bank, 2013; Waissbein et al., 2013).

The paper is structured as follows. The Background on Indonesia's electricity sector, rural electrification and RVGs section introduces the context of this study. The Methods section provides an overview of the methods applied. In the Potential returns of RVGs in Indonesia section we identify return sources. The Investment barriers and measures for investors to address them section provides the results of a detailed barrier analysis (that is needed to understand risks) as well as a comprehensive selection of multiple measures to assist investors to address these aforementioned barriers. We then turn to the role of regulation and discuss our findings in the Discussion section with regard to the role of national policy for improving the risk/return

profiles of RVGs. We end with the Conclusion section summarizing our findings briefly.

Background on Indonesia's electricity sector, rural electrification and RVGs

The Indonesian State Constitution from 1945 declares that all vital utilities concerning the greater population must be controlled by the state. Since 1985, the electricity sector in Indonesia has been controlled by the state-owned power utility Perusahaan Listrik Negara (PLN). After its formation, PLN became the sole body responsible for the provision of electricity across Indonesia. The Ministry of Energy & Mineral Resources serves as the policy making body and regulator for PLN. However, other ministries within the GoI are also stakeholders providing different governing and support functions. In a bid to boost the capacity of electricity generation and keep up with an estimated 9% annual demand growth (Differ Group, 2012; Permana et al., 2012), the GoI since 2009 has opened up the market of power generation for competition. Small scale independent power producers (IPPs) can now produce electricity, but are required to sell it to PLN for distribution. Only rural cooperatives are allowed to generate and distribute electricity independently of PLN. Fig. 1 shows a schematic of key players in the Indonesian electricity sector and their roles. In order to address climate change and reduce its oil dependency, the GoI has also introduced The Ministerial Decree on Renewable Energy Resources and Conservation (Ministerial Decree No. 002/2004) which aims at increasing the share of renewable energy to 18% by 2025 (Energypedia, 2013).

Despite having significantly developed its generation, transmission and distribution network over the years, the national electricity grid remains significantly strained. The growth in generation capacity has been unable to keep up with the growth in electricity demand. Since 2009, the Java–Bali transmission grid is particularly congested, which has led to "transmission bottlenecks" that often forced PLN to impose rolling blackouts across the two main islands of Java and Sumatra. However, the more remote islands mainly suffer from partial or even complete lack of electricity. With an electrification ratio of about 65%–70%,[4] about 72–84 million of the 242 million Indonesians still do not have access to reliable and affordable electricity services (Asia Sustainable and Alternative Energy Program, 2005; Energypedia, 2013; PT Perusahaan Listrik Negara, 2010; Purwono, 2008; Winoto et al., 2012). Of these 72–84 million people the vast majority, about 60 million, reside in rural areas and almost all live outside of the most densely populated islands[5]: Fig. 2 shows the electrification ratios per province and clearly indicates that the eastern parts of Indonesia particularly are suffering from a lack of access to electricity. Despite these official figures, it has been very difficult to quantify the real progress at the rural village level.

Previous studies suggest that due to the challenging geographical nature of the country, a decentralized off-grid electrification solution is more appropriate than grid extension, in particular for remote and rural villages in mountainous areas and on smaller islands (Blum et al., 2013; Boedoyo and Sugiyono, 2010; Kaundinya et al., 2009; Sovacool and Valentine, 2011). Currently, most village grids are powered by diesel plants: at the end of 2007, 936 decentralized diesel power plants (50 kW–500 kW) with a total capacity of 987 MW were operating in Indonesia (Senoaji, 2008). Diesel generators are a standard rural electrification solution, due to their long track-record, reliability, scalability, availability

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[2] Another — non-empirically driven — reason for the choice of Indonesia was the fact that one of the authors is an Indonesian native, which strongly improved the accessibility of data gained in literature reviews and during field trips (see Methods section).

[3] Additionally, international initial capital can potentially be extended by carbon financing (compare Quantitative approach section).

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[4] Electrification figures diverge depending on the source and the interpretation of electrification; often electrification ratios reflect general access to electricity, but do not reflect the quantity and quality of the accessed electricity (*Interviews*). In Indonesia a village counts as 'electrified' if at least one location within the villages is connected to PLN's low voltage grid — which includes mainly diesel powered village grids. A clearer indication of the true electrification ratio would be the number of electrified households (see Fig. 2).

[5] Indonesia consists of about 17,508 islands, out of which around 6000 are inhabited (The CIA World Factbook, 2013).
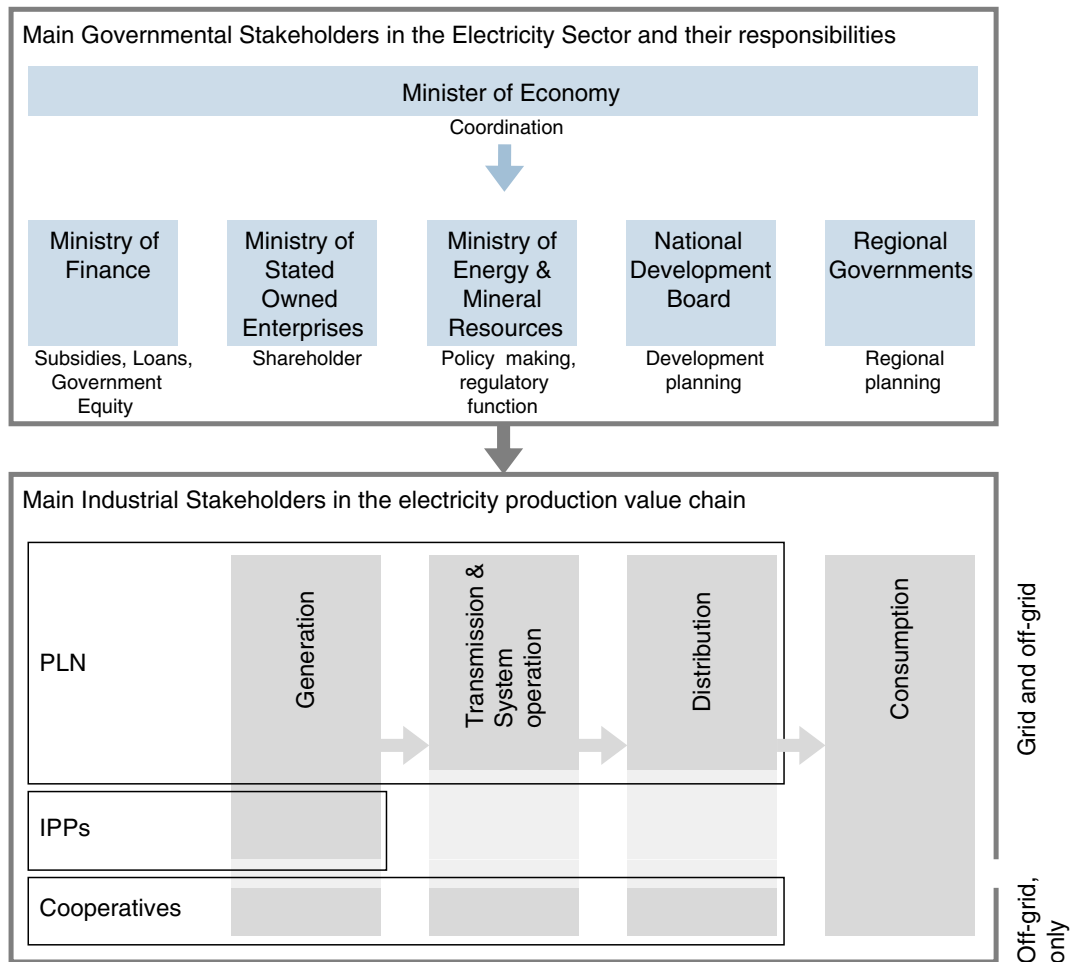
Fig. 1. Governmental and industrial stakeholders in the Indonesian Electricity Sector.
Adapted from PWC (2011) and Purra (2009).

and relatively low upfront cost (ESMAP, 2007). However, in line with the GoI's aim to increase the share of renewables in electricity generation, RVGs are largely considered to be a suitable alternative to improve rural electrification while at the same time not increasing greenhouse gas emissions (Beck and Martinot, 2004; ESMAP, 2007; Terrado et al., 2008; White et al., 2008).

While PLN aims at erecting solar powered village grids on several hundred islands within the next years (through the "1000 Islands

Fig. 2. Indonesian electrification ratios (number of electrified households) per province. Own graph based on data from 2011 from the Indonesian Ministry of Energy and Mineral Resources (Kusdiana, 2012; Winoto et al., 2012).
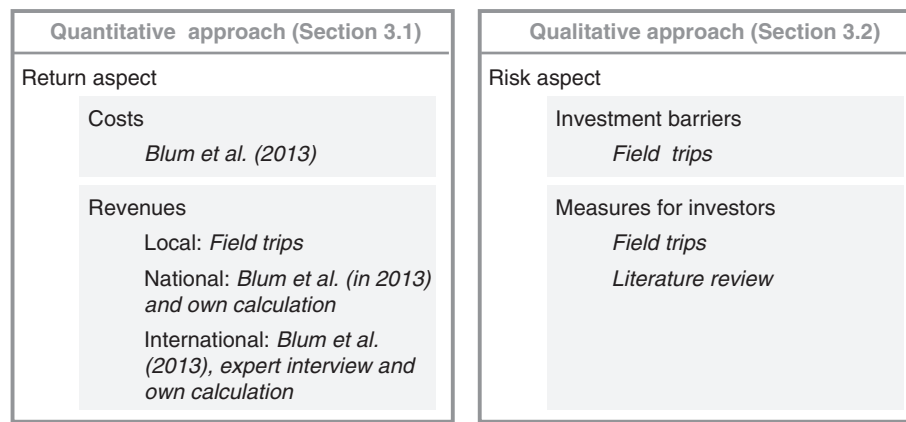
Quantitative approach (Section 3.1)	Qualitative approach (Section 3.2)
Return aspect	Risk aspect
Costs *Blum et al. (2013)*	**Investment barriers** *Field trips*
Revenues Local: *Field trips* National: *Blum et al. (in 2013) and own calculation* International: *Blum et al. (2013), expert interview and own calculation*	**Measures for investors** *Field trips* *Literature review*

Fig. 3. Quantitative and qualitative research approach to determine return and risk aspects (data sources are indicated in italics).

Project"), only on few islands have projects been realized thus far. At the same time, only few private sector activities, such as the social business IBEKA, exist. International initiatives include Energizing Development (EnDev) and RewiRE, or UNDP's support, e.g., for Yayasan Bina Kitorang Mandiri (YBKM).

Methods

In terms of methods, the suggestion by Schäfer et al. (2011) was followed to perform research in the field of rural electrification by integrating the expertise of practitioners with the knowledge of different academic disciplines. To this end, quantitative — for the return aspect — and qualitative methods — for the risk aspect — were used in this study. Both, the quantitative and the qualitative parts are based on the field trips and literature. Fig. 3 provides an overview of the quantitative and qualitative approaches along with the data sources used.

Quantitative approach

The quantitative methods are used to estimate potential returns, i.e., the revenues minus the costs. Revenues can stem from three different levels: the local (village) level, the national and the international levels. The cost and the revenue estimates are based on two main sources first, three field trips (lasting in total 6 weeks) to Indonesia in July 2011 and March 2012; second, literature.

To determine local revenues, we conducted 19 interviews with implementers and operators of RVGs, as well as villagers. As such data on potential revenues through electricity sales (local revenues) has not been thoroughly documented thus far or the appropriate data within literature was insufficient,[6] we gathered own data: In these interviews build–own–operate (BOO) investors and villagers revealed the current tariffs, which were determined through community agreements and therefore can be assumed to reflect their willingness to pay (WTP).[7]

To analyze the costs as well as the potential national and international revenues, we draw from literature, mainly from data

provided in a paper by Blum et al. (2013). As this paper is such an important source, it is briefly summarized here with a further explanation of which of their cost data we use and how national and international revenue streams were derived from their data: By means of a levelized cost of electricity (LCOE) model, Blum et al. (2013) investigate the economics of micro, hydro, and solar PV/battery powered village grids in Indonesia and compare them to the LCOE of conventional diesel powered village grids. The paper assumes a generic Indonesian village, determines the village's demand curve along with the size of the power plants needed to meet this demand (for assumptions see Table 1). Amongst others, the paper provides results for the LCOE of diesel, micro hydro and solar PV/battery powered village grids. While the latter two results directly inform our cost data, we used the diesel LCOE to estimate national revenues.

In specific, we calculated the "potential" national and international revenue streams as follows. First, national revenue streams encompass diesel and electricity subsidies. The actual value of diesel subsidies (in USD/kWh) in currently operating diesel powered village grids was determined by the difference between the LCOE of diesel powered village grids at Indonesian and at world diesel prices (as given by Blum et al., 2013). The difference between the LCOE of diesel powered village grids (at Indonesian diesel prices) and the Indonesian national electricity tariff (charged by PLN and paid by already electrified rural poor households) yields current electricity subsidies. Second, to determine international revenues in the form of carbon certificates (in USD/kWh), we use Blum et al. (2013) result on the absolute yearly emission reduction potential (205.4 tCO_2/village/year) and multiply it with the yearly produced electricity and a carbon price of 9–15.5 USD/tCO_2.[8] For local, national and international revenue streams, average values along with sensitivities (indicated by ranges), and data sources please refer to Annex A.

Qualitative approach

For the barrier analysis, we conduct — as suggested by Yin (2003) for studying complex contemporary phenomena — qualitative research. Extensive field research with a desktop literature review was combined to explain investment barriers and measures for investors to address them. In such an explanation building process one often iterates between literature and field research (Yin, 2003). This is also the case in our study. During the field trip of 2011 the general market situation of RVGs was studied in Indonesia and when combined with desktop research the research question was narrowed down and helped in the preparation for the second field trip of 2012. The data collected so far was then complemented by another round of literature review. The

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[6] Three literature sources provided data on local revenues through electricity sales in Indonesia, White et al. (2008) report a WTP of 0.08–0.7 USD/kWh, while Feibel (2010) provides real tariffs of 20 micro hydro power plants (10 in each Sulawesi and Sumatra) of about 0.07 USD/kWh in 2010. Abraham et al. (2012) report a WTP of 0.4 USD/kWh. Besides the existence of these studies, we decided to collect new data for three reasons: (a) The first study's data comes from 2000 and is therefore likely to be outdated; (b) the data from Feibel (2010) refers to real tariffs in micro hydro powered village grids in very specific regions and thus indicates prices which are much lower than the WTP; (c) the WTP provided by Abraham et al. (2012) was regarded as unrealistically high by our interviewees.

[7] However, it is probably the lower end of the villagers' WTP as villagers in such community agreements typically set the tariffs at the lower end of what they are able to pay.

[8] An interview with an active expert in the carbon market revealed that these prices are paid to Gold Standard certified projects — for more on Gold Standard projects and points of critique see Nussbaumer (2009) or Rogger et al. (2011).

Table 1
Selected assumptions from Blum et al. (2013).

Village size		1475 people living in 350 households
Electricity demand of the village		Electricity is available 24 h per day for households (day and night), productive use (majority during daytime), and social infrastructure (majority during daytime). –Daily electricity demand of the whole village: 558.5 kWh
Electricity supply	Diesel system	A diesel system encompasses a diesel generator. –Assumed capacity: 69.6 kW
	Micro hydro system	Micro hydro power describes hydroelectric power up to about 100 kW. A prerequisite for micro hydro systems are rivers with adequate water flow rates, head and water availability. –Assumed capacity: 69.6 kW
	Solar PV/battery system	Solar PV systems, which directly convert solar energy into electricity, combined with battery storage are a usual rural electrification option. A prerequisite for solar PV/battery systems are high irradiation. In our calculations we assume a solar PV system which consists of crystalline silicon (cSi) solar PV panels connected to advanced lead–acid batteries. –Assumed capacity: 232.5 kWp (solar PV), 716 kWh (battery)

following paragraphs refer to our interview sampling approach, the content of the literature review and the analysis of the data.

When performing field trips within Indonesia different kinds of relevant actors were included as an important strategy for the sampling, to allow the capture of different perspectives on perceived barriers/risks. We conducted semi-structured interviews[9] with six private sector actors, eight representatives from the public sector, four employees of development agencies, and three representatives of non-profit organizations. Six of the interviewees were interviewed twice within a time interval of one year. Additionally, four private sector actors who are operating RVGs in Lao PDR or Cambodia were interviewed; their insights were used to triangulate and strengthen the analysis on measures for investors (for more details on interviewees compare Annex B). While several interviews were conducted in English those interviews with non-English speaking actors were supported by a translator or conducted by the native Indonesian speaking co-author of this study.[10] To further triangulate the interview results, we visited four operating mini grids (two of them in Indonesia, and one in Lao PDR and Cambodia) and collected feedback upon presenting our research at the International Conference on Sustainable Innovation at the Universitas Muhammadiyah Yogyakarta, Indonesia.

The in-depth literature review encompasses scientific articles and practical literature (reports, case studies, project information) on two topics. First, literature on investment barriers for RVGs in Indonesia was consulted. Second, literature on measures for investors to address barriers such as business model features, best practices and lessons learnt to overcome barriers to RVGs was included. This second kind of literature was not restricted to Indonesia.[11]

To analyze the collected data, the recorded interviews and interview notes were transcribed. These transcripts were then coded for barriers and the measures to address them. We grouped barriers thematically as well as along the local, national and international levels in order to obtain a final list of barriers. In a last step we matched the barriers with suitable measures stemming from the field research and the reviewed literature.

Potential returns of RVGs in Indonesia

As discussed in the Introduction section, RVGs are assumed to become attractive for investors if there is a cost–revenue situation which allows for positive returns. Other authors claim that "most of the mini-grid projects suffer from non-viability as cost of electricity generation from such projects is high while the return through tariff is low"[12] (Palit and Chaurey, 2011, p. 274). However, they only refer to the local revenue stream (the tariffs) and omit additional potential revenue sources from the national and international levels. Contrarily, this study considers potential revenue streams on all three levels: local, national and international. We structure the description of the potential revenue streams along these three geographical levels (compare Annex A).

Revenues on the local level refer to electricity sales to the villagers. While some authors independent from Indonesia argue to use villagers' income levels (or also sometimes referred to as ability to pay) as proxy for local revenues others suggest considering the WTP (Zerriffi, 2011).[13] WTP includes other factors besides income levels, for example educational levels or kerosene consumption (Komatsu et al., 2011; Phuangpornpitak and Kumar, 2011; UN AGECC, 2010) and is therefore understood to be more accurate. We therefore consider WTP in our analysis. Our obtained data reveals that WTP ranges from 0.12 to 0.25 USD/kWh and turns out to be considerably higher than PLN's electricity tariff for poor rural households connected to the grid (0.09 USD/kWh).

At the national level, we look at potential revenue streams from a re-distribution of national subsidies. Previous studies have shown the detrimental effect of fossil fuel subsidies (especially for renewable energies) (Blum et al., 2013; Fattouh and El-Katiri, 2012; IISD, 2011; Schmidt et al., 2012). Subsidy phase-out is a difficult endeavor generally (UNEP, 2008) and in Indonesia (Mourougane, 2010), we argue that a re-distribution of subsidies towards renewable energy projects could be less problematic (compare the Discussion: The role of government in attracting private investment section). The underlying assumption is that RVGs replace a diesel powered village grid, which would otherwise be built. Diesel is the standard technology for village grids in Indonesia (Blum et al., 2013; Senoaji, 2008). The subsidies that the diesel village grid would receive could generate an additional revenue stream if passed on to the RVG. There are currently two kinds of subsidies in the Indonesian electricity tariff system (Braithwaite et al., 2012; Differ Group, 2012; Gunningham, 2013; Permana et al., 2012). First, a fuel subsidy which protects local diesel prices against world price

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[9] As part of each interview, we compiled a background analysis of written data, such as websites and media coverage, which we used to customize interview guides.

[10] On average, interviews lasted 60 min and were conducted face-to-face with the exception of one telephone interview. Interviews were recorded when acceptable to the interviewee; if not, the interviewer took detailed notes.

[11] In contrast to the barrier analysis, we included literature from different countries and on different rural electrification technologies to identify measures to address the barriers. The underlying assumption is that similar barriers can be solved by similar measures.

[12] Palit and Chaurey (2011) state that the high cost is associated to capital, operation and management costs and the low returns are linked to low incomes and therefore low financial ability to pay for electricity.

[13] Literature is not consistent regarding the question whether the WTP is lower (Cook, 2011; Martin, 2009) or higher (Zerriffi, 2011) than the villager's ability to pay, but concludes that a) the WTP and the ability to pay have to be balanced (Roland and Glania, 2011) and b) the WTP varies greatly between countries (White et al., 2008).

fluctuations.[14] And second — as PLN sells at fixed prices, also in off-grid areas — an electricity subsidy bridges the gap between the government-regulated retail electricity tariffs (0.08–1.04 USD/kWh) and the real cost of electricity supply across the PLN network (electricity production cost is 0.09–0.35 USD/kWh)[15] (Blum et al., 2013; Braithwaite et al., 2012; Haeni et al., 2008; IISD, 2011; Mourougane, 2010; Permana et al., 2012). Re-distributing the fuel subsidies to RVGs could result on average in 0.30 USD/kWh of revenues, re-distributing the electricity subsidies on average in additional 0.39 USD/kWh.

At the international level, we consider carbon credits as a potential revenue stream. RVG projects reduce (existing and marginal) CO_2 emissions — at the height of 0.96 $kgCO_2$/kWh (Blum et al., 2013) — while providing the possibility of economic development for a village. Additionally, under the current political subsidy environment they are not per se profitable. For these reasons they qualify for receiving premium priced carbon credits, e.g., certified by the Gold Standard (The Gold Standard Foundation, 2012). The resulting revenues range from 0.009 to 0.016 USD/kWh.

Fig. 4 compares these potential revenues and the costs. The cost data by Blum et al. (2013) show that micro hydro powered RVGs[16] exhibit substantially lower life-cycle generation costs than solar PV/battery powered RVGs, which are caused by higher investment costs for the solar PV modules and batteries. Our results reveal that locally sourced revenues can fully cover the RVG's cost in the case of micro hydro, meaning that investors can realize RVGs with a relatively small need to tap into national and international revenue streams. In the case of solar PV/battery powered RVGs, the local revenue stream only covers 17%–36% of the (much higher) generation costs.[17] However, one has to keep in mind that the WTP, and therefore local revenue streams, can vary strongly with income and location (White et al., 2008). It is probable that WTP rises with the increase of productive activities based on electricity.[18] When looking at revenue streams on the national level, we find significant effects of potential subsidies on the return of RVG projects (compare also IISD, 2011): Our results suggest that in all cases, a re-distribution of fuel and electricity subsidies (at the height presently found in the Indonesian fuel market and for electricity generated by PLN) towards RVGs have the potential to cover the majority of the production cost. For micro hydro powered RVGs, the contribution from a full re-distribution of either one of the subsidy types would by far over compensate the costs of a typical project (by 64% and 114% calculated for the average values). For solar PV/battery powered RVGs, the contribution from shifted fuel subsidies can account for 23%–58%, and electricity subsidies for 28%–77% of production costs. At the international level, we identify that revenues from carbon credits could yield only between 5% and 9% of the production cost of micro hydro powered RVGs and 1%–2% of the production cost of solar PV/battery powered RVGs — which originates from low carbon prices (which might even further decline) (Point Carbon, 2013). Our findings support earlier claims stating that it is "extremely difficult to make carbon financing economically viable for rural electrification projects" (Yadoo, 2012).

When summing up all potential revenues, we find that this sum in both RVG types exceeds the respective costs. This indicates that RVGs

can potentially yield profits of 0.07–0.57 USD/kWh. While micro hydro powered RVGs can often be financed with local revenues only, the solar PV/battery powered RVGs heavily depend on further revenue streams (see the Discussion: The role of government in attracting private investment section). Theoretically, RVGs get higher potential returns the further away they are from the national grid due to potentially higher benefits from a subsidy re-distribution. While our results highlight that a major barrier for the diffusion of solar PV/battery powered RVGs lies in a not yet favorable cost–revenue balance, it can be assumed that at least in the case of micro hydro powered RVGs the reason for the non-diffusion originates from additional risks.[19] Investors typically face many barriers when trying to secure the underlying cash flows which can translate into investment risks (Glemarec, 2012; Waissbein et al., 2013). To understand the low diffusion rate of RVGs (and especially of micro hydro powered village grids) one therefore needs to analyze these barriers as done in the next section.

Investment barriers and measures for investors to address them

To address the risks specific to RVGs in Indonesia, we first identify the barriers through a barrier analysis. These barriers can stem from stakeholders on the local, national or international level, i.e., the same levels as the revenue sources. The barriers can translate into investment risks in the planning, construction and operational phase, which might discourage investors from investing (or increase financing costs and thereby the generation costs) (Glemarec et al., 2012; Waissbein et al., 2013). In a second step, we turn to the role of BOO investors[20] and discuss how they could become active in addressing the underlying challenges. By doing so we highlight the important role of investors in mitigating investment risks, which — as a literature review revealed — is an often neglected aspect in research on RVGs (Bhattacharyya, 2011, 2012; Kaundinya et al., 2009). Table 2 provides an overview of the barriers and measures for investors for each the local, national and international level. The following sub-sections are structured along these three levels and describe barriers as well as the corresponding measures. Whenever the information is based on literature we cite the respective studies whereas information based on interviews is referred to as *Interviews* (details on the specific *Interview* sources are provided in Annex C).

Local level

On the local level we identified five barriers which transform into challenges for BOO investors and can be addressed by specific measures.

Lack of understanding the customers' needs

In order to assure the sustained success of an RVG, projects ought to be seen rather as projects improving the livelihood of villagers than as mere energy projects (Kumar et al., 2009; UNDP, 2011). To this end, investors must understand their investment context, including also user practices (Johnson, 2013). In our interviews, Indonesian practitioners stated that RVG projects often suffer from understanding the needs of their customers (*Interviews*), i.e., the villagers who consume and pay for the produced electricity. Doing successful business requires knowing these customers and their needs and designing products and services accordingly. BOO investors specifically face the challenges of an "electricity is for free" mindset, difficulties in collecting electricity fees, avoiding electricity theft, and sensitively handling their position as monopolists (*Interviews*). To address these challenges BOO investors could start by *conducting market research to understand village specifics* (Roland and Glania, 2011; Sovacool et al., 2011b; UNEP, 2005). Market

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[14] This fuel subsidy is reaching unsustainable levels and increasingly becoming a major strain on the GoI's spending (Braithwaite et al., 2012; Differ Group, 2012; Haeni et al., 2008; IISD, 2013; Permana et al., 2012).

[15] The higher prices refer to more remote areas where electricity provision is more expensive.

[16] A study by the IFC (Bardouille et al., 2012) calculated the costs of micro hydro powered RVGs at around 19.5 USD/kWh supporting Blum et al. (2013).

[17] The IFC (Bardouille et al., 2012) calculates costs of 0.34 USD/kWh for a solar PV (without battery) powered RVG. However, such a configuration is capable of covering electricity demands during daytime only, and does therefore not satisfy household needs, which mainly occur in the evening (Blum et al., 2013; IIEC, 2006; Saengprajak, 2006).

[18] However, as long as PLN tariffs remain at the rate of 0.09 USD/kWh villagers living relatively close to the national grid will not be willing to pay a tariff which is twice this price.

[19] Blum et al.'s (2013) LCOE calculation already assumes an elevated risk level (as typical in the energy sector in Indonesia) via the discount rate of 12.5% (UNFCCC, 2010).

[20] We assume BOO investors, as the barriers can affect all phases of the project cycle.
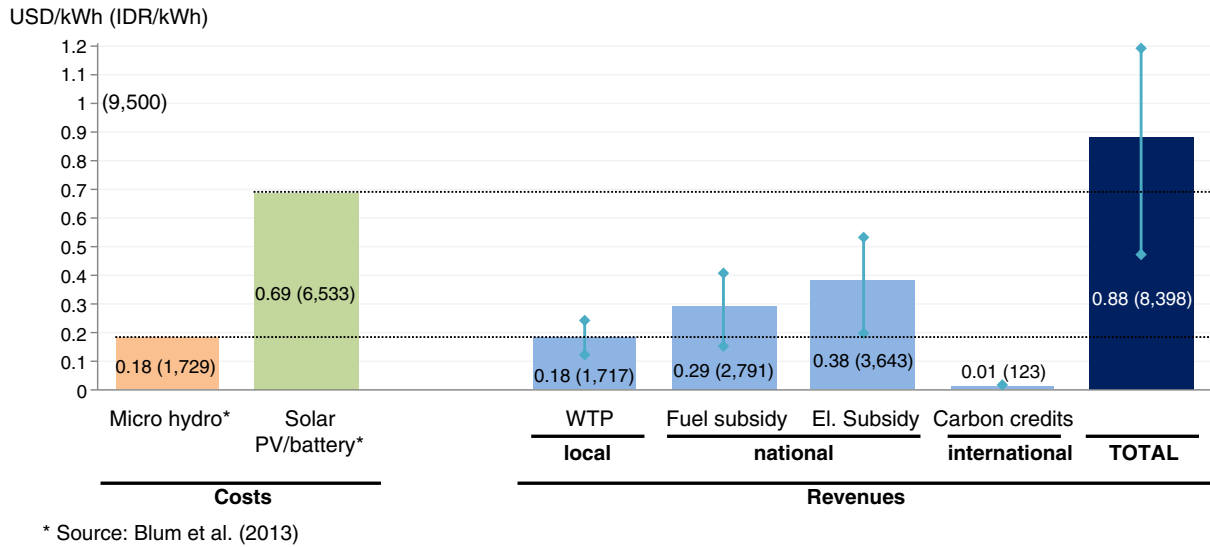
Fig. 4. Cost and revenue estimates for micro hydro and a solar PV/battery powered RVGs. Values are in USD/kWh and those in brackets in IDR/kWh. An exchange rate of 9500 IDR/USD is assumed.

research tools which are recommended for rural contexts are home stays, field trips,[21] contacts with competitors and cooperation with local organizations. In a second step, *customer service can be introduced* (Bambawale et al., 2011; Bardouille et al., 2012; De Vries et al., 2010; Gradl and Knobloch, 2011; Roland and Glania, 2011; Sovacool et al., 2011a, 2011b). Such service consists of proper maintenance services including product performance guarantees and warranties as well as regular visits in the villages in order to collect feedback. Further, these activities can be supported by *involving the community*[22] actively (Yadoo and Cruickshank, 2010; Sovacool et al., 2011b; *Interviews*) also with a sensibility for the BOO investor's own position as monopolist. Concrete activities include stakeholder meetings (Bardouille et al., 2012; Rickerson et al., 2012), in-kind support for villagers (Rickerson et al., 2012; Sovacool and Valentine, 2011), co-operation with existing income-generating organizations (e.g., coffee or rice farmers) (Aron et al., 2009), and community ownership[23] and management[24] (Aron et al., 2009; Glemarec, 2012; Yadoo, 2012). Such community activities are time-consuming, yet as experts from other NGOs state, a prerequisite for customer acceptance (Alvial-Palavicino et al., 2011; *Interviews*).

Lack of decentralized operation, maintenance and administration

Typically Indonesian organizations (including rural electrification organizations) tend to implement centralized structures with head-quarters in Jakarta or other major cities. However, this is not the most effective structure in a decentralized, rural context as local presence matters (see the Lack of understanding the customers' needs section). BOO investors are consequently challenged by long travel distances and complicated distribution channels (*Interviews*). Hence, practitioners are convinced that BOO investors would benefit from

implementing a decentralized organizational structure (*Interviews*), referring to small, independent and flexible units (Schmidt and Dabur, 2013). When implementing such structure, assuring a continuous knowledge flow between the sub-units is crucial to distribute learning by doing and using (see the Lack of understanding the customers' needs section). The decentralized structure is strengthened by employing locals, even if skilled labor is scarce (compare the Lack of skilled local human resources section). Concrete actions are, e.g., the training of own, local staff, sub-contracts with local business partners (e.g., franchises) or cooperation with local organizations (Rickerson et al., 2012; Yadoo and Cruickshank, 2010).[25]

Unsteady electricity demand and uncertain forecasts

Our field studies revealed that due to the variety of villages across Indonesia with respect to population, prosperity, cultural and social structure, the demand for rural electricity services can vary greatly[26] (*Interviews*). This makes it challenging for BOO investors to estimate electricity demand and future growth in demand levels. BOO investors are therefore urged to take measures to understand the current demand and to perform demand forecast scenarios. This involves a basic assessment of each village in the development phase of the RVG. The system is then sized accordingly incorporating future extension of production capacities (Rickerson et al., 2012). The latter is influenced by possible population and economic growth which can be reinforced by access to electricity (Roland and Glania, 2011). As it is "essential to introduce flexibility and scalability right in the planning phase" (*Interview with public sector representative*), BOO investors can increase their flexibility in meeting a growing demand by increasing the modularity and flexibility in the design of the RVG.[27] This allows integrating future capacity, e.g., by adding power sources such as solar panels and integrating several RVGs into a smaller regional grid. In practice, the creation of a smart (real time metering) flexible system increases the relevance and robustness of the RVG (Bardouille et al., 2012; Bazilian et al., 2011; Dean et al., 2012; Rickerson et al., 2012). Educating customers on efficient electricity use is a supportive measure

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[21] However, the practitioner guide REED Toolkit (UNEP, 2005) questions the quality of responses gathered during field trips.

[22] While the village chiefs might be good entry points for investors, involving more villagers benefits feedbacks from users, especially as the local governments' capacity is often limited (*Interviews*). Additionally, the concept of user innovation (Von Hippel, 2005) might be considered in an RVG service context.

[23] Perceived community ownership (or sometimes also referred to as cooperative approach) is more important than actual legal ownership (Yadoo, 2012).

[24] Possible disadvantages of community-centered models can be the time intensity to establish the cooperative, as well as the risk of technical and financial failure over time and the dependence on the community members (Glemarec, 2012). Yadoo and Cruickshank (2010) and Cook (2011) on the other side stress that operation and management costs are lower in cooperatives and Palit and Chaurey (2011) explains that "due to equity, commitment and transparency" cooperatives are successful. They also show that this holds particularly true if there is a productive use of electricity.

[25] The positive side effect of employing locals are the shared responsibilities for service and maintenance as well as independent operations and management (Dasappa et al., 2011; Gradl and Knobloch, 2011; Yadoo, 2012).

[26] The uncertainty stems — amongst others — from misuse, or overuse of electricity and unknown economic development of the village.

[27] Programs such as Paladin Live by Power Analytics help to plan adjustments in the system size. This particular program shows the capacity, availability and reliability of a RVG by analyzing real time data (Dean et al., 2012).

Table 2
Barriers and measures for investors to address them (in Indonesia).

	Barriers (based on interviews)	Measures for investors to address the respective barrier (based on literature review and interviews)
Local (Local level section)	Lack of understanding the customers' needs	Conduct market research to understand village specifics Introduce customer service Involve the community
	Lack of decentralized operation, maintenance and administration	Implement a decentralized organizational structure Employ locals
	Unsteady electricity demand and uncertain forecasts	Do scenarios for the demand forecast of each village Increase modularity and flexibility of design of the RVG Educate customers on efficient electricity use Agree with local businesses on fixed and regular electricity purchases
	Lack of local human resources	Train and up-skill own, local staff Retain trained and skilled staff
	Lack of local financial resources	Design a locally adapted tariff and payment scheme Foster local productive use and entrepreneurship Provide customers with access to loans
National (National level section)	Lack of standards and knowledge transfer on best practices	Draw from and advocate for existing best practice examples and standards Conduct pilot projects, then scale up
	Lack of information and data	Collect and share information and data
	Lack of national network of investors	Attend and conduct workshops, seminars and conferences Build strategic partnerships
	Lack of national technology supplier network	Buy from local suppliers whenever possible Buy from international suppliers where necessary
	Strongly regulated electricity market	Advocate for market liberalization
	Ineffective governmental structures	Maintain professional contacts to governmental units in order to gain trust Decentralized operation, maintenance and administration
	Lack of national financial resources (debt and equity)	Reduce business risk Employ new financing schemes
International (International level section)	Lack of international financial resources (debt, equity, carbon)	Reduce business risk Employ new financing schemes Loan from impact investors Apply for carbon credits
	Negative externalities caused by international donors	Strengthen NGOs, governmental agencies and other non-private actors in their understanding of free market mechanisms

which helps to shape electricity demands (Bazilian et al., 2011; Cook, 2011; Glemarec, 2012; Rickerson et al., 2012; Yadoo and Cruickshank, 2010, Interviews). Finally, arranging fix priced buy-off agreements with small local businesses[28] (where possible) lowers insecurities in the electricity forecasts (Bardouille et al., 2012).

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[28] Including base-load customers like mobile telephone companies (powering their towers) might decrease the relative load variability, however, system costs might raise strongly, especially in case of solar-powered RVGs, where the battery capacity needs to be increased to cover consumption during the night.

Lack of skilled local human resources

While in 2008 the average Indonesian adult illiteracy rate was at 7.8% (UNESCO, 2009), this rate is much higher in rural areas where RVGs are implemented.[29] Consequently the lack of skilled (and motivated) local human resources in rural Indonesia to build, operate and manage RVG power plants[30] represents a major barrier (Interviews) and BOO investors cope with the challenge of identifying and employing skilled local staff. In a first step they therefore employ, train and up-skill own, local staff (Bardouille et al., 2012; Yadoo, 2012) and possibly also cooperate with local micro and small enterprises in order to enhance technology transfer and ensure long-term maintenance (Aron et al., 2009; Feibel, 2010; Rickerson et al., 2012; Roland and Glania, 2011; Interviews). Public financial resources sourced from international organizations, NGOs and the government can be invested to create a supporting "capacity building unit". Training tools, cooperation with local academic institutions (Rickerson et al., 2012) or peer-to-peer trainings (De Vries et al., 2010) have proven successful in practice. In a second step, the trained and skilled staff have to be retained, which can be fostered through fair salaries (Interviews), potentially also performance-dependent salaries (Roland and Glania, 2011) or additional benefits such as health insurance or housing programs.

Lack of local finance

Finally, in rural Indonesia the villagers lack financial resources (Interviews). On the one hand, villagers have low income levels; on the other hand a banking system providing loans to rural locals is absent (Monroy and Hernandez, 2005) and as an interviewee from the private sector states "The villagers won't be able to get funding and realize a RVG project on their own. Typically they'd have to turn to some sort of institution" (Interview with private sector representative). BOO investors have the challenging task to implement a business approach that targets poor customers (also referred to as an inclusive business approach). Only if energy access is affordable, rural electrification of the poor is sustainable (UNDP, 2011). In the case of RVGs such an approach can be threefold; (a) a locally adapted tariff and payment scheme starts with the determination of the tariff.[31] Such a tariff results from balancing commercial viability and the consumer's WTP (Roland and Glania, 2011; Interviews) while considering levels of demand and supply (Rickerson et al., 2012). Furthermore, the payment has to be organized in an efficient way for customers and the BOO investor[32] (Bardouille et al., 2012; Gradl and Knobloch, 2011). For tariffs as well as for actual payments, BOO investors will profit from incorporating the villagers' preferences as well as from ensuring clear definitions and high transparency (Roland and Glania, 2011; Interviews). (b) In the long run, private investors in RVGs also benefit from fostering local productive use and entrepreneurship (Monroy and Hernandez, 2005), because with the economic development of the village the

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[29] A report by the Indonesian Ministry of Education and Culture (2012) states the following illiteracy rates for Tenggara: 10–16%; West Sulawesi: 10%; and Papua: 36%. All three regions have rural electrification rates below 60% (compare Fig. 2).

[30] An analysis by the IFC (Bardouille et al., 2012, p. 92) found that "skills development and capacity building are not major concerns for most small power providers" of diesel powered village grids, however that RVGs "require higher levels of technical sophistication to operate smoothly". We are not aware of any government program which systematically trains villagers as village grid technicians.

[31] Proven tariff schemes (mainly based on Roland and Glania, 2011) are the "graded electricity tariff system" where tariffs are based on pre-determined capacities, "electricity-based tariffs" where electricity meters in households monitor the use of electricity and consumers pay per kWh, "pre-paid mechanisms" where customers pay in advance for a certain amount of electricity and a load limiter then regulates the access to electricity, or "demand regulating tariff schemes" where tariffs react to electricity production (Rickerson et al., 2012). Ideally also future maintenance cost is included in the tariffs (Aron et al., 2009).

[32] The following factors are at discussion in this matter; the occurrence (monthly, weekly, with harvest), the kind of payment (cash, "in kind"), and the collection (trained villagers, mobile payment, prepaid payment, leasing of electricity appliances) (Yumkella et al., 2010; Roland and Glania, 2011; Bardouille et al., 2012; Bellanca and Wilson, 2012; Glemarec, 2012; Interviews).

customers' purchasing power increases and results in a higher likelihood of sustained future cash flows (Aron et al., 2009; Bardouille et al., 2012; Roland and Glania, 2011). Concrete actions that foster productive use and entrepreneurship are e.g., business incubation services (Bellanca and Wilson, 2012), entrepreneurial trainings (Yadoo, 2012) and encouraged trade between villages. Besides capacity building, "soft aid" can be provided, such as technical and agricultural equipment at low-cost, e.g., machinery for agro-processing, seeds and live-stock (Aron et al., 2009; Gradl and Knobloch, 2011; Interviews). Also investments in complementary infrastructures such as roads and the communication system support entrepreneurial efforts and trade (Yadoo, 2012). (c) BOO investors can provide their customers with access to loans (Glemarec, 2012; Monroy and Hernandez, 2005) for production equipment powered by electricity. As besides equipment, villagers with entrepreneurial intentions[33] often require training and loans. Common ways to provide villagers with this access to finance are via cooperation with local micro-finance institutions and/or local commercial banks, e.g., the Indonesian Bank Perkreditan Rakyat or People's Development Bank (DB Climate Change Advisors, 2011), or by integrating micro-finance into the BOO investors' own business model and offering tailored financial vehicles to local entrepreneurs.[34] However, such investors currently have few RVGs in their lending portfolios as they prefer more small scale electrification options (such as solar home systems or solar lantern businesses) or grid extension due to these concepts' lower complexity and hence lower investment risks (Interviews).

National level

On the national level we identified seven barriers which BOO investors should address.

Lack of standards and knowledge on best practices

Despite the more than 900 RVG projects and pilots across Indonesia, there is still a lack of standards, certification and knowledge transfer on the best practices of management and operation (Interviews). In order to close this gap, BOO investors can heavily draw from and advocate for existing best practices and standards[35] (Roland and Glania, 2011; Interviews), while ensuring that own best practices and standards are advocated through publications, conferences and seminars. Own attempts are leveraged by cooperating with peer public and private stakeholders. The development of own best practices eventually emerges from conducting robust pilot projects and scaling them up without too much deviation (Drewienkiewicz, 2005; Feibel, 2010; Interviews).

Lack of information and data

In Indonesia, as well as in many other non-OECD countries, there is often a lack of reliable data on natural resources (water flow in rivers, wind strengths, irradiation, and rain fall), population and infrastructure in rural areas (Interviews). BOO investors have to close this information gap by own means in order to be able to e.g., identify villages which could be promising business cases. Activities include the collection and sharing of information and data, which involves own investigations in villages, accessing and improving existing data bases (such as Aviation and Aerospace Agency Indonesia, 2013; Bureau of Statistics Indonesia, 2012; Energypedia, 2013), and sharing and distributing data through partners such as universities and national research institutes (Interviews).

Lack of national network of investors

Despite efforts by the Indonesian Ministry of Energy to synchronize RVG projects, there is currently only little coordination ongoing between different organizations and projects (Interviews). This testifies to the absence of national networks. Often, this results in stand-alone projects and few spillovers of knowledge and experience. BOO investors can act as stimulants in the creation of such networks. They can attend and conduct workshops, seminars and conferences in order to get in touch with public and private organizations within and outside of Indonesia (Interviews). Furthermore, they can invest in strategic partnerships with private and public actors (UNEP, 2005), e.g., through collaboration in market analysis, project implementation, financing or through formal long-term contracts with contractors and suppliers.

Lack of national technology supplier network

Even if Indonesia managed to increase general production levels, this holds only partly true for the technological components of RVGs; locally produced micro hydro turbines do exist, but barely any solar photovoltaic panels, switch gears and control panels. This results in a limited local technology supplier network as most suppliers are from outside Indonesia (Interviews). The consequences are not so much higher cost — Indonesia has enacted a VAT and duty exemption for renewable energy core components (The Pew Charitable Trusts, 2011) — but long delivery times for parts for repair or capacity extension. BOO investors face the trade-off of choosing from the limited selection of Indonesian suppliers (if at all available), accepting longer delivery times (and thus potentially longer outages), or having higher stocks which involve fixed capital. The recommended approach is to buy from local suppliers if possible (Interviews) and with this contribute to the extension of a national technology supplier network. This will keep the investor's fixed capital low and reduce delivery times for spare parts. If local suppliers are absent, buy from international suppliers, while considering stocking up with the most important spare parts (Interviews). This reduces dependence on international delivery times while keeping fixed capital limited.

Strongly regulated electricity market

The Indonesian electricity market is strongly regulated (Interviews, see also the Background on Indonesia's electricity sector, rural electrification and RVGs section) resulting in fixed sales tariffs including heavy fuel and electricity subsidies (see e.g., Blum et al., 2013) and in PLN's dominance over IPPs and cooperatives in terms of power production. The latter is likely to change due to the opening of the power market since 2009. However, this partly liberalized market still limits BOO investors' freedom of action and lacks incentives for private investments. Measures as advocating for market liberalization can be undertaken (Interviews). However, such efforts are challenging and resource intensive (see the Discussion: The role of government in attracting private investment section for policy recommendations).

Ineffective governmental structures

Practitioners observe that "there are 36 Ministries in Indonesia, several of them have rural electrification programs, yet still there is little cooperation" (Interview with a development agency representative). Due to the large number of national Indonesian governmental entities involved in rural electrification (going far beyond the Ministry of Energy and Resources or rural development), there are often overlapping functionalities and a lack of transparency.[36] The role of regional

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[33] Lemaire (2011) shows the example of solar home systems that access micro credits to support the creation of a dynamic self-sustained market for rural electrification through renewable energy.

[34] Most beneficial for villagers would be access to loans at lower than usual interest rates (Van Mansvelt, 2011).

[35] IEC (International Electrotechnical Commission, 2013) Technical Specification Series 62257 provides, amongst others, useful standards for village grids (Roland and Glania, 2011).

[36] Also more generally (i.e., independent from RVGs), Indonesia's institutional structures are hampering private sector engagement. This is for instance reflected by Indonesia's rank in the Ease of Doing Business Ranking — 128 out of 185 — (The World Bank, 2013) and in the Corruption Perceptions Index (Transparency International, 2013) — 118 out of 174.

governmental entities is rather marginal (compare also Fig. 1). Furthermore, existing national regulations, and support schemes for rural electrification and renewable energy are not fully implemented yet. BOO investors can only indirectly address these facts by maintaining professional contacts to regional governmental units in order to gain trust and to leverage the units' importance (Interviews). Finally, this could incentivize the national government to implement a more decentralized, flexible approach. Additionally, BOO investors benefit from decentralized operation, maintenance and administration (compare the Lack of decentralized operation, maintenance and administration section), e.g., by employing locals who are familiar with the governmental structure and by implementing an organizational structure which combines strong central offices in main cities with decentralized, flexible branches in order to cope with the governmental structure (Interviews).

Lack of national financial resources (equity and debt)

Similar to the very scarce financial resources at the local level, there is also a lack of equity sponsors and Indonesian banks that provide capital at reasonable financing cost (for international equity and debt sponsors see the Lack of international financial resources (debt, equity, carbon) section) (Aron et al., 2009; Interviews). The most important measure that BOO investors can undertake in this regard is to reduce business risks. Common actions which reduce these risks are cost-effective choices of technologies[37] (Bardouille et al., 2012; Rickerson et al., 2012; UNEP, 2005; Interviews), management and operation models, the bundling of projects in order to increase the market size and with this the attractiveness of investments (Roland and Glania, 2011), the provision of guarantees for debt and equity investors (such as first loss risk guarantees, loan guarantees) if existent[38] (Bellanca and Wilson, 2012; Roland and Glania, 2011), and finally a sound business plan (UNEP, 2005). Further, BOO investors can employ new financing schemes (Aron et al., 2009; Chaurey et al., 2012; Glemarec, 2012; Rickerson et al., 2012; Interviews) such as combined loan equity schemes where e.g., soft loans from private investors are combined with community equity or public–private loan schemes where loans are partially provided by private actors and partially by public actors such as a development agency or the government (such undertakings are also called Private Public Partnerships[39]). In our interviews, a non-profit sector representative stated: "Through the establishment of collateral (i.e., register a company for the single RVG) we demonstrate to the private investor the potential of a stable return. This becomes sort of a mini IPP scheme" (Interview with non-profit sector representative).

International level

On the international level we identified two major barriers, which transform into challenges for BOO investors and can be addressed by specific measures.

Lack of international financial resources (debt, equity, carbon)

As financial resources on the local and national levels are tight, BOO investors try to tap international resources. However, there is also a lack on the international level which again hits BOO investors in their struggle for funding (Interviews). It requires keeping up with international standards and involves higher transaction costs as well

as currency challenges as equity and debt are usually provided in USD or EUR and not in the Indonesian currency IDR. The measures introduced in the Lack of national financial resources (equity and debt) section (reducing business risks and employing new financing schemes) are applicable, however can be extended by two additional measures: Besides from commercial banks, BOO investors can lend from impact investors which accept higher risks at lower rates of return (Bellanca and Wilson, 2012; Interviews). However, impact investors' due diligences can be slow and more laborious as they cannot rely on standard financial assessments alone, but also collect data on e.g., social and environmental impacts (Yadoo, 2012). Also their budget is limited compared to that of commercial banks. Concerning the measure of applying for carbon credits (Glemarec, 2012); even if today there already existed a tailored carbon market product which would fit the requirements of RVGs, e.g., the Clean Development Mechanism (CDM) or its Programme of Activities (PoA), applying for carbon credits has drawbacks. They have a low financial potential as shown in the Methods section and the transaction costs for participating in carbon markets are high (Ascui et al., 2007; Michaelowa and Jotzo, 2005; Michaelowa et al., 2003; Schneider et al., 2010). However if the CDM/PoA are understood as a quality insurance they potentially could lower business risks and help in accessing equity and loans.[40]

Disturbing international donor influence

It occurs that Indonesian private and public actors perceive international involvement as disruptive to national and local efforts in rural electrification, especially when it hinders the development of a private market (Interviews). First, one can observe that international donor organizations that consult Indonesian policy makers often follow their own agenda and miss out on coordinating their efforts with other international and national actors (Interviews). Furthermore, international donor organizations compete on the Indonesian job market for the most skilled and trained employees (international and Indonesian ones). In this struggle for labor, international donor organizations typically attract the best employees as they pay high salaries. In a labor market with a limited number of skilled labors, this results in a lack of skilled employees for the private and the local public sectors (Interviews). Reacting to such a market environment involves dialog with international donor organizations in order to strengthen their understanding of free market practices and their importance for sustainable development (Bellanca and Wilson, 2012).

Discussion: The role of government in attracting private investment

Our results in the Potential returns of RVGs in Indonesia and Investment barriers and measures for investors to address them sections have shown that RVGs in Indonesia can potentially be an interesting business case for private investors if managed well. However, the findings also reveal that the investors' room for maneuvering is limited. In order to increase the diffusion rate, the investment environment and hence the risk/return profiles of RVGs need to be further improved via government action (see also Roland and Glania, 2011). In Indonesia with its centralistic governmental organization (compare the Background on Indonesia's electricity sector, rural electrification and RVGs section), such action has to mainly come from national regulatory institutions. Two topics seem to be most important: subsidy re-distribution (compare the Potential returns of RVGs in Indonesia section); and improving the investment environment through public action (compare the Investment barriers and measures for investors to address them section).

Currently fossil fuel and other (non-renewable) energy subsidies in Indonesia are amongst the highest in non-OECD countries (Braithwaite

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[37] The village grid modeling software HOMER (Hybridization Optimization Model for Electric Renewables) identifies the most cost effective option for RVGs (Dean et al., 2012).

[38] While single RVGs might not be able to access such financial instruments due to scale and transaction cost issues, the bundling of projects might open-up such access.

[39] An even more focused variation of the Private Public Partnership is the Pro-Poor Public Private Partnership where the villagers are considered as consumers that receive benefits while at the same time being partners for business ventures.

[40] We regard it as rather speculative whether RVGs in Indonesia might profit from future additional climate finance (e.g., provided by the Green Climate Fund).

et al., 2012; Haeni et al., 2008; Mourougane, 2010). Due to the increasing pressure of these subsidies on public budgets and their negative effects in encouraging energy efficiency, the government is currently in the process of implementing subsidy reforms. However, reductions and abolition of subsidies in Indonesia are a very sensitive topic and tied politically as phasing out subsidies can have negative social effects, especially for the poor (Braithwaite et al., 2012; Mourougane, 2010). For example, in 2012 "plans to raise subsidized fuel prices […] failed to get the majority in the voting for approval from the House of Representatives" (Permana et al., 2012, p. 21). The situation might be different when re-distributing subsidies from fossil fuels to renewable energy (DB Climate Change Advisors, 2011). Subsidy shifts towards RVGs' leverage private investments into rural electrification. It is hence the poorest communities — those without electricity — that would profit most. So the rationale of subsidies (to support the livelihood of the poor) would be upheld while removing their negative environmental side effects.

The results shown in Fig. 4 (Potential returns of RVGs in Indonesia section) highlight that per unit of electricity delivered especially by micro hydro projects only needs a small fraction of the subsidies, which are currently embodied in diesel based off-grid electricity generation. This is — to a lesser extent and depending on location — also often valid for solar PV/battery powered RVGs. Therefore, for RVGs to replace the standard option (diesel powered village grids), not all subsidies that would be embodied in diesel based electricity generation would have to be re-distributed fully. Hence, through subsidy re-distribution public money could be saved and in fact these savings could increase over time. Assuming increasing global fossil fuel prices, diesel subsidies would have to be increased over time in order to keep end-consumer prices in Indonesia relatively stable. At the same time, due to falling technology costs, especially in the case of solar PV/battery powered RVGs (ESMAP, 2007; IRENA, 2012; Peters et al., 2011), the re-distributed subsidies of future projects will have to be much lower; similar to a subsidy phase-out over time. Subsidy reform could also help to terminate the misperception that diesel powered village grids exhibit lower costs than RVGs[41] (Blum et al., 2013).

From a climate perspective, as diesel generators can be regarded as the business-as-usual solution for rural electrification in Indonesia (Haeni et al., 2008), a re-distribution of subsidies from fossil fuels to renewable off-grid technologies would substantially reduce the baseline emissions from rural electricity generation in Indonesia. In a recent article, Schmidt et al. (2012) argue that subsidy phase-out could be an integrated part of Nationally Appropriate Mitigation Actions[42] (NAMAs) and should be encouraged through future climate finance schemes. Along the same line, we argue that subsidy re-distributions could potentially be credited as unilateral contribution to climate finance. Note that in order to assure efficiency of public spending, re-distributed subsidies should be paid based on the performance of a project instead of solely providing grants for equipment upfront (Ghosh et al., 2012). Furthermore, subsidies should only be one part of the revenue streams for private investors. Local payments for energy should especially be an integral part of the RVG business models. Finally, over-subsidization should be avoided (compare e.g., Hoppmann et al., 2013 for some negative impacts of over-subsidization in developed countries).

While our paper is focused on RVGs in Indonesia, the above thoughts also generally hold true for most off-grid technologies for other non-OECD countries, with low electrification rates, large decentralized renewable energy potentials and high subsidies for fossil-based electricity generation.

The second aspect where government action is required concerns improving the investment environment apart from a fuel subsidy reform. Our analysis (Investment barriers and measures for investors to address them section) shows that a whole array of barriers (translating into risks) stands in the way of private investments. While BOO investors can address many barriers via their business models (mainly those on the local level), others (mainly on the national level) go beyond their sphere of influence. Many of these barriers can translate into investment risks — scaring off investors and/or increasing financing costs. As the risk/return profile of projects must be attractive for investors and in the current situation RVG investments in Indonesia underlie high risks, only few investors with large risk appetite can be attracted (explaining the very low diffusion rate of privately financed RVGs).

Two recent UNDP studies (Glemarec et al., 2012; Waissbein et al., 2013) show that improving the investment environment by reducing the investment risks can attract new private investments and lead to lower financing costs and thereby substantially lower electricity generation costs. While these studies focus on on-grid renewable energy, we assume that this is generally also the case for RVGs, as they are typically also based on a project finance structure, and therefore discuss them in light of our results.[43] The UNDP defines two ways of de-risking renewable energy investments: financial instruments (e.g., guarantees or risk insurance) and policy instruments (e.g., technology standards or improved energy legislation). While the former mitigates the financial impact in the case of a negative event affecting the project, the latter reduces or entirely removes the barriers that underlie the risks and thereby reduces the probability of a negative event occurring. Using the example of on-shore grid connected wind energy, their study shows that both financial and policy de-risking is effective and efficient.

In the case of RVGs, the economic efficiency of financial instruments — if they are available at all — is more questionable; due to the small project scales of RVGs and the high transaction costs, these instruments can be expected to be very costly on a per kW basis. A solution to this might be the bundling of projects (e.g., through the CDM's PoA) so that the scale (e.g., in terms of kW) is increased and the impact of the transaction costs reduced at least to some extent. Together with the typically higher cost of financial instruments (compare Waissbein et al., 2013) this lack of micro-financial de-risking instruments and lower efficiency means that the role of policy instruments gets even more important in the case of RVGs. Other than for financial instruments, the economic efficiency of policy instruments is much less correlated with the individual project size but rather with the size of total investment that occurs on the national (in case of national policy instruments) or regional level (in case of sub-national instruments). Therefore, policy instruments to improve the investment environment should primarily act on the national/regional level, similarly as Waissbein et al. (2013) argue in the case of on-grid renewable energy. From our findings in the Investment barriers and measures for investors to address them section and reflecting upon insights from Glemarec et al. (2012) and Waissbein et al. (2013) the following four policy actions seem most effective in order to improve the

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[41] Widely spread in Indonesia as an interviewee confirmed "Rural Electrification through renewable energy has two problems: People can't afford it and the government can't afford to provide it" (Interview).

[42] NAMAs are a key element in international climate negotiations and describe "sets of policies and actions tailored to the circumstances of individual countries that they agree to undertake as part of their commitment to reduce emissions." (Höhne, 2011, p. 32; Michaelowa et al., 2012).

[43] We are aware that the risk categories partly differ between on-grid and RVG projects, e.g., due to different stakeholders involved. However, our discussion refers to the general line of thought that de-risking is essential for project-finance-based private investment.

investment environment for RVGs and thus reduce some predominant risks:

1. Energy market risk: Conduct a reform of the national renewable energy and electrification policies in order to align them. Part of this reform should be the effectively improved market access for private BOO investors and a re-distribution of subsidies (see above).
2. Institutional/licensing risk: Reduce overlapping functionalities and partly diverging programs of government bodies and agencies. Similar to Waissbein et al. (2013) a "one-stop-shop" for RVGs could be created and equipped with the necessary executive competences. Such a RVG body could also be responsible for collecting and exchanging data (e.g., on renewable energy potentials, technologies or suppliers).
3. Technology risk: Introduce technology standards for RVGs so that suppliers, BOO investors and end-consumers have a good basis for their contracts and so that transaction costs are reduced (see also Roland and Glania, 2011).
4. Financial risk: To improve the access to finance, the newly founded Indonesian Climate Change Trust Fund (ICCTF) could prioritize the support of RVGs. Special small scale finance vehicles for BOO investors could be designed and offered (see the Lack of local finance section).

While this is just a very short list, further action could improve the investment environment and thereby leverage the diffusion of RVGs. Very important in this regard is educating investors (meaning both debt and equity sponsors), as they are often not familiar with the investment opportunities in off-grid projects. Generally, investors perceive projects in rural areas as riskier than projects in urban areas (Rickerson et al., 2012). By putting this risk perception in perspective, private investors could become more interested in RVGs (Roland and Glania, 2011). The results on how to improve the investment environment for RVGs are country specific. In order to formulate policy recommendations for other countries, we regard a barrier analysis for that country as indispensable.

All the proposals discussed in this section promise to substantially increase the attractiveness of RVGs for private investors. However, we are fully aware that implementing these proposals would not be easy. The role of the political economy is pervasive when it comes to such reform projects, but discussing its role would go far beyond our research and the scope of this paper.

Conclusion

In this paper we ask how the risk/return profile of RVGs can be improved in order to attract private investments. First, we focus on the return aspect and identify potential local, national and international revenue streams for RVGs and compare them to costs. The analysis shows that potential local and national revenue streams are able to cover costs and therefore build the base for a profitable business case, at least in case of micro hydro powered village grids. While local revenue estimates are based on the WTP for electricity, national revenues are based on potentially re-distributed subsidies, both revenue streams are substantial. The role of international revenues in the form of climate credits turns out to be limited. Second, in order to understand the risk aspect, the paper analyzes investment barriers on a local, national and an international level and matches them with measures that BOO investors can take to remove the barriers. We find a wide range of measures for investors; however, we argue that BOO investors cannot solve the low diffusion of RVGs by themselves and that policy reforms are needed. The two most important governmental activities in this regard include the re-distribution of fossil fuel subsidies towards RVGs and public de-risking measures such as reforming the national renewable and electrification policies, reducing overlapping functionalities, introducing technology standards for RVGs, and improving access to finance.

Annex A

Table A1
Potential revenue streams with lower and upper bound of considered values.

Revenue streams		USD/kWh (IDR/kWh)	Method of determination	Sources
Local level	Willingness-to-pay (WTP)	Average: 0.18 (1729) Range: 0.12–0.24 (1136–2285)	The range is determined through the lowest and highest available tariffs currently paid in Indonesian RVGs. These are determined through community agreements. The average is un-weighted.	Data from non-commercial RVG project field surveys interviews
National level	Fuel subsidies	Average: 0.29 (2791) Range: 0.15–0.41 (1420–3866)	Diesel subsidies are calculated by subtracting the global fuel prices from the local fuel prices (following IEA's opportunity cost approach).	IEA (2010)
	Electricity subsidies	Average: 0.38 (3643) Range: 0.20–0.53 (1865–5039)	Electricity subsidies are calculated by subtracting PLN's tariff from the LCOE of a diesel powered village grid (at Indonesian prices). The ranges are a function of location: fuel gets more expensive the more remote it is used; therefore the lower value is applicable for more central RVGs. The average represents medium distance from fuel distribution centers	
International level	Carbon credits	Average: 0.01 (9.5) Range: 0.009–0.016 (86–152)	The yearly emission reduction potential of a village (205.4 tCO_2/village/year) is divided by the yearly electricity production (365 days $*$ 558.5 kWh/village/ day) which yields a relative emission reduction potential (0.001 tCO_2/kWh). This multiplied with the carbon price of 9–15.5 USD/tCO_2, results in potential carbon revenues in USD/kWh. The range is determined by the range of carbon prices. The average is un-weighted.	The Gold Standard-official website (2012) interviews

Annex B

Table B1
Overview of interviews for the risk analysis.

	Interviewed persons in different organizations (org.)		Geographical scope	Risk aspects	
	2011	2012		Barriers	Measures
Private sector (Prv)	Org. 1 Person A Org. 1 Person B Org. 1 Person C	Org. 1 Person A Org. 1 Person B	Indonesia	X	X
		Org. 2 Person A	Indonesia	X	X
		Org. 3 Person A	Indonesia	X	X
	Org. 4 Person A		Lao PDR		X
	Org. 4 Person B				
	Org. 5 Person A		Cambodia		X
	Org. 6 Person A		Cambodia		X
	Org. 7 Person A		Global		X
Public sector (Pub)	Org. 8 Person A		Indonesia	X	X
	Org. 8 Person B				
	Org. 8 Person C				
	Org. 9 Person A		Indonesia	X	X
		Org. 10 Person A	Indonesia	X	X
		Org. 10 Person B			
		Org. 11 Person A	Indonesia	X	X
		Org. 11 Person B			
Development agencies (Dev)	Org. 12 Person A	Org. 12 Person A	Indonesia	X	X
	Org. 12 Person B	Org. 12 Person B			
	Org. 12 Person C	Org. 12 Person C			
		Org. 12 Person D			
Non-profit sector (Npr)	Org. 13 Person A	Org. 13 Person A	Indonesia	X	X
		Org. 13 Person B			
		Org. 14 Person A	Indonesia	X	X

Annex C

Table C1
Barriers, measures and respective interview sources.

	Barrier interview sources[a]		Measures to address the respective barrier interview sources[a] (For literature review sources see respective sections in the main text)	
Local (Local level section)	Lack of understanding the customers' needs	Prv, Dev, Npr	Conduct market research and understand village specifics	
			Introduce customer service	
			Involve the community	Npr
	Lack of decentralized operation, maintenance and administration	Prv	Implement a decentralized organizational structure	
			Employ locals	
	Unsteady electricity demand and uncertain forecasts	Prv, Pub, Dev	Do scenarios for the demand forecast of each village	
			Educate customers on efficient electricity use	Npr
			Agree with local businesses on fixed and regular electricity purchases	
			Increase modularity and flexibility of design of the RVG	
	Lack of local human resources	Prv, Dev	Train and up-skill own, local staff	Prv, Pub
			Retain trained and skilled staff	Npr
	Lack of local financial resources	Prv, Pub, Dev, Npr	Design a locally adapted tariff and payment scheme	Npr
			Foster local productive use and entrepreneurship	Npr
			Provide customers with access to loans	Prv
National (National level section)	Lack of standards and knowledge transfer on best practices	Prv, Pub, Dev	Draw from and advocate for existing best practice examples and standards	Npr
			Conduct pilot projects, then scale up	Prv, Dev
	Lack of information and data	Prv	Collect and share information and data	Dev
	Lack of national network of investors	Prv	Attend and conduct workshops, seminars and conferences	Prv, Npr
			Build strategic partnerships	
	Lack of national technology supplier network	Prv	Buy from local suppliers whenever possible	Prv, Npr
			Buy from international suppliers where necessary	Prv, Npr
	Strongly regulated electricity market	Prv	Advocate for market liberalization	Npr
	Ineffective governmental structures	Prv, Pub, Dev, Npr	Maintain professional contacts to governmental units in order to gain trust	Prv
			Organize company in a decentralized, flexible structure while employing locals	Prv
	Lack of national financial resources (debt and equity)	Prv, Npr	Reduce business risk	Prv, Npr
			Loan from impact investors	Npr
			Employ new financing schemes	Prv, Npr
International (International level section)	Lack of international financial resources (debt, equity, carbon)	Prv, Npr	Reduce business risk	Prv, Npr
			Loan from impact investors	Npr
			Employ new financing schemes	Prv, Npr
			Apply for carbon credits	
	Negative externalities caused by international donors	Prv, Dev	Strengthen NGOs, governmental agencies and other non-private actors in their understanding of free market mechanisms	

[a] Abbreviations: Prv = private sector, Pub = public sector, Dev = development agencies, Npr = non-profit sector.

References

Abraham K, Phadke H, Riaz M, Strahl J. REwiRE: rural electrification with renewable energy. Meet the REwiRE team; 2012 [Presentation].

Alvial-Palavicino C, Garrido-Echeverría N, Jiménez-Estévez G, Reyes L, Palma-Behnke R. A methodology for community engagement in the introduction of renewable based smart microgrid. Energy Sustain Dev 2011;15(3):314–23.

Anon. The Gold Standard — official website. . Available at:http://www.cdmgoldstandard. org. [Accessed October 25, 2012].

Aron J-E, Kayser O, Liautaud L, Nowlan A. Access to energy for the base of the pyramid. Paris, France and Washington D.C., USA: Hystra and Ashoka; 2009.

Ascui F, Kaiser M, Austin M, Helfferich V. Guidebook to financing CDM projects. Roskilde, Denmark: UNEP (United Nations Environment Programme), Riso and EcoSecurities; 2007.

Asia Sustainable and Alternative Energy Program. Indonesia. Available at: http://web. worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/EXTEAPASTAE/0, contentMDK:21042053~menuPK:2900515~pagePK:64168445~piPK:64168309~theSiteP-K:2822888,00.html, 2005. [Accessed October 25, 2012].

Aviation and Aerospace Agency Indonesia. Lembaga Penerbangan dan Antariksa. Available at:http://www.lapan.go.id/, 2013. [Accessed January 3, 2013].

Bambawale MJ, D'Agostino AL, Sovacool BK. Realizing rural electrification in Southeast Asia: lessons from Laos. Energy Sustain Dev 2011;15(1):41–8.

Bardouille P, Avato P, Levin J, Pantelias A, Engelmann-Pilger H. From gap to opportunity: business models for scaling up energy access. Washington D.C., USA: International Finance Corporation (IFC); 2012.

Bazilian M, Hobbs BF, Blyth W, MacGill I, Howells M. Interactions between energy security and climate change: a focus on developing countries. Energy Policy 2011;39(6):3750–6.

Beck F, Martinot E. Renewable energy policies and barriers. Encycl Energy 2004:1–22.

Bellanca R, Wilson E. Sustainable energy for all and the private sector. London, UK: International Institute for Environment and Development (IEED); 2012.

Bhattacharyya SC. Special issue on off-grid electrification in developing countries. Energy Sustain Dev 2011;15(3):201–2.

Bhattacharyya SC. Review of alternative methodologies for analysing off-grid electricity supply. Renew Sustain Energy Rev 2012;16(1):677–94.

Blum NU, Sryantoro Wakeling R, Schmidt TS. Rural electrification through village grids — assessing the cost competitiveness of isolated renewable energy technologies in Indonesia. Renew Sustain Energy Rev 2013;22:482–96.

Boedoyo MS, Sugiyono A. Decentralized power generation in Indonesia: current issues and prospects. Tech Monitor; 201031–6 [May–Jun].

Braithwaite D, Chandra A, Diah P, Indriyanto A, Lang K, Lontoh L, et al. Indonesia's fuel subsidies: action plan for reform. Geneva, Switzerland: International Institute for Sustainable Development (IISD); 2012.

Bureau of Statistics Indonesia. Badan Pusat Statistik. Available at:www.bps.go.id/, 2012. [Accessed January 3, 2013].

Chaurey A, Krithika PR, Palit D, Rakesh S, Sovacool BK. New partnerships and business models for facilitating energy access. Energy Policy 2012;47:48–55.

Climate Change Advisors DB. GET FiT plus: de-risking clean energy business models in a developing country context. DB Climate Change Advisors, Deutsche Bank Group; 2011.

Cook P. Infrastructure, rural electrification and development. Energy Sustain Dev 2011;15(3): 304–13.

Dasappa S, Subbukrishna DN, Suresh KC, Paul PJ, Prabhu GS. Operational experience on a grid connected 100 kWe biomass gasification power plant in Karnataka, India. Energy Sustain Dev 2011;15(3):231–9.

De Vries M, Flink T, Kauw K, van der Vleuten F, Mulder T. Business models for energy access. Leusden, The Netherlands: ETC Foundation and Enabling Access to Sustainable Energy (EASE); 2010.

Dean M, Jolly N, Trifonov S. Microgrids: the BRICS opportunity. Zpryme Research & Consulting; 2012.

Deichmann U, Meisner C, Murray S, Wheeler D. The economics of renewable energy expansion in rural Sub-Saharan Africa. Energy Policy 2011;39(1):215–27.

Differ Group. The Indonesian electricity system — a brief overview, Oslo, Norway; 2012.

Drewienkiewicz R. GVEP/UNDP documentation and analysis of business models within the E + Co portfolio. Global Village Energy Partnership (GEVP) and United Nations, Development Programme (UNDP); 2005.

Energypedia. Indonesia country situation. Available at:https://energypedia.info/index. php/Indonesia_Country_Situation, 2013. [Accessed October 25, 2012].

ESMAP. Technical and economic assessment of off-grid, mini-grid and grid electrification technologies. Washington D.C., USA: Energy Sector Management Assistance Program (ESMAP); 2007.

ESMAP. Maximizing the productive uses of electricity to increase the impact of rural electrification programs. Washington D.C., USA: Energy Sector Management Assistance Program (ESMAP); 2008.

Fattouh B, El-Katiri L. Arab human development report — energy subsidies in the Arab world. Oxford, UK: Oxford Institute for Energy Studies and United Nations Development Programme (UNDP); 2012.

Feibel H. How micro hydro power systems implemented during ENDEV 1 are performing. St. Gallen, Switzerland: Entec AG and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ); 2010.

Gallagher KS, Holdren JP, Sagar AD. Energy–technology innovation. Annu Rev Environ Resour 2006;31(1):193–237.

Ghosh A, Müller B, Pizer W, Wagner G. Mobilizing the private sector — quantity-performance instruments for public climate funds. Oxford Energy and Environment Brief; 20121–15 [August].

Glemarec Yannick. Financing off-grid sustainable energy access for the poor. Energy Policy 2012;47:87–93.

Glemarec Yannick, Rickerson W, Waissbein Oliver. Transforming on-grid renewable energy markets: a review of UNDP-GEF support for feed-in tariffs and related price

and market-access instruments. New York, USA: United Nations Development Programme (UNDP)/Global Environment Facility; 2012.

Gradl C, Knobloch C. Energize the BoP! Energy business model generator for low-income markets. Berlin, Germany: Endeva; 2011.

Gunningham N. Managing the energy trilemma: the case of Indonesia. Energy Policy 2013;54:184–93.

Haeni JH, Green C, Setianto E. Indonesia energy assessment. Washington, USA: USAID; 2008.

Höhne N. Policy: changing the rules. Nat Clim Change 2011;1(1):31–3.

Holland CW, Derbyshire W. Electrifying 20 million households — an Indonesian rural electrification strategy. EEA Conference & Exhibition June 2009. Christchurch 2009.

Hoppmann J, Peters M, Schneider M, Hoffmann VH. The two faces of market support — how deployment policies affect technological exploration and exploitation in the solar photovoltaic industry. Res Policy 2013;42(4):989–1003.

IEA. World Energy Outlook 2010, Paris, France; 2010.

IIEC. Demand side management best practices guidebook for Pacific Island power utilities. Suva, Fiji Islands and New York, USA: South Pacific Applied Geoscience Commission (SOPAC), United Nations Department of Economic and Social Affairs (UNDESA), and International Institute for Energy Conservation; 2006.

IISD. A citizen's guide to energy subsidies in Indonesia. Geneva, Switzerland: International Institute for Sustainable Development (IISD); 2011.

IISD. Global subsidies imitative. Available at:http://www.iisd.org/gsi/, 2013. [Accessed February 17, 2013].

International Electrotechnical Commission. Technical specification series 62257. . Available at:http://www.iec.ch/index.html. [Accessed March 1, 2013].

IRENA. Solar photovoltaics, Abu Dhabi, United Arab Emirates; 2012.

Johnson O. Universal energy access: moving from technological fix to poverty reduction, Bonn, Germany; 2013.

Kanagawa M, Nakata T. Analysis of the energy access improvement and its socio-economic impacts in rural areas of developing countries. Ecol Econ 2007;62(2):319–29.

Kaundinya DP, Balachandra P, Ravindranath NH. Grid-connected versus stand-alone energy systems for decentralized power — a review of literature. Renew Sustain Energy Rev 2009;13(8):2041–50.

Komatsu S, Kaneko S, Shrestha RM, Ghosh PP. Nonincome factors behind the purchase decisions of solar home systems in rural Bangladesh. Energy Sustain Dev 2011;15(3): 284–92.

Kumar A, Mohanty P, Palit D, Chaurey A. Approach for standardization of off-grid electrification projects. Renew Sustain Energy Rev 2009;13(8):1946–56.

Kusdiana D. Indonesia: renewable energy policies and regulation. Challenges in incentivizing RE development and rural electrification; 2012 [Presentation].

Legros G, Havet I, Bruce N, Bonjour S. The energy access situation in developing countries — a review focusing on the least developed countries and Sub-Saharan Africa. New York, USA: United Nations Development Programme (UNDP) and World Health Organization (WHO); 2009.

Lemaire X. Off-grid electrification with solar home systems: the experience of a fee-for-service concession in South Africa. Energy Sustain Dev 2011;15(3):277–83.

Macharia E, Gupta G, Tsan M. Solar lighting for the base of the pyramid — overview of an emerging market. Dalberg Global Development Advisors, Lighting Africa, and, International Finance Corporation (IFC); 2010.

Martin S. Generating income with renewable energy — preliminary lessons learned from an innovative public–private partnership in Laos; 2009 [Presentation].

Michaelowa A, Jotzo F. Transaction costs, institutional rigidities and the size of the clean development mechanism. Energy Policy 2005;33(4):511–23.

Michaelowa A, Stronzik M, Eckermann F, Hunt A. Transaction costs of the Kyoto mechanisms. Clim Policy 2003;3:261–78.

Michaelowa A, Dransfeld B, Blodgett C, Galante A, Basu A, Eschmann M. IRENA handbook on renewable energy nationally appropriate mitigation actions (NAMAs) for policy makers and project developers. Abu Dhabi, United Arab Emirates: IRENA (International Renewable Energy Agency); 2012.

Ministry of Energy & Mineral Resources of Indonesia. Harga Pembelian Tenaga Listrik oleh PT PLN dari Pembangkit Listrik Terbarukan Skala Kecil dan Menengah atau Kelebihan Tenaga Listrik; 2009 [Jakarta, Indonesia].

Monroy C, Hernandez A. Main issues concerning the financing and sustainability of electrification projects in rural areas: international survey results. Energy Sustain Dev 2005;9(2):17–25.

Mourougane A. Phasing out energy subsidies in Indonesia. OECD Economcis Department working papers, no. 808. Paris, France: OECD Publishing 2010.

Nussbaumer P. On the contribution of labelled certified emission reductions to sustainable development: a multi-criteria evaluation of CDM projects. Energy Policy 2009;37(1):91–101.

OECD/IEA. World Energy Outlook 2011 — energy for all — financing access for the poor, special early excerpt of the World Energy Outlook 2011. Paris, France: International Energy Agency (IEA); 2011.

Ölz S, Beerepoot M. Deploying renewables in Southeast Asia — trends and potentials. Paris, France: International Energy Agency (IEA); 2010.

Palit D, Chaurey A. Off-grid rural electrification experiences from South Asia: status and best practices. Energy Sustain Dev 2011;15(3):266–76.

Permana AD, Sugiyono A, Boedoyo MS, Oktaufik MAM. Outlook Energi Indonesia 2012. Jakarta, Indonesia: Badan Pengkajian dan Penerapan Teknologi (BPPT); 2012.

Peskett L. The history of mini-grid development in developing countries. Policy briefing by GVEP, 3 Suppl 1. 2011. p. 143–6. [1119168].

Peters M, Schmidt TS, Wiederkehr D, Schneider M. Shedding light on solar technologies — a techno-economic assessment and its policy implications. Energy Policy 2011;39(10): 6422–39.

Phuangpornpitak N, Kumar S. User acceptance of diesel/PV hybrid system in an island community. Renew Energy 2011;36(1):125–31.

Point Carbon. EU ETS eligible sCER price forecast. Available at:http://www.pointcarbon. com/research/promo/research/1.2009586?&ref=searchlist, 2013. [Accessed January 4, 2013].

PT Perusahaan Listrik Negara. Going through the 2008 global financial crisis; 2010 [Presentation].

Purra MM. The Indonesian electricity sector: institutional transition, regulatory capacity and outcomes. Singapore: National University of Singapore; 2009.

Purwono J. Harga Patokan Dalam Pembelian Tenaga Listrik Dari Pembangkit Tenanga Listrik Swasta; 2008 [Presentation].

PWC. Electricity in Indonesia — investment and taxation guide. Jakarta, Indonesia: PricewaterhouseCoopers (PWC); 2011.

Rickerson W, Uppal J, Glassmire J, Lilienthal P, Sanders E, Colson C, et al. Renewable energies for remote areas and islands (REMOTE). Paris, France: International Energy Agency-Renewable Energy Technology Deployment (IEA-RETD); 2012.

Rogger C, Beaurain F, Schmidt TS. Composting projects under the clean development mechanism: sustainable contribution to mitigate climate change. Waste Manag (N Y) 2011;31(1):138–46.

Roland S, Glania G. Hybrid mini-grids for rural electrification: lessons learnt. Brussels, Belgium: Alliance for Rural Electrification (ARE)/USAID; 2011.

Saengprajak A. Efficiency of demand side management measures. Small village electrification systems. Kassel University; 2006 [PhD Thesis].

Schäfer M, Kebir N, Neumann K. Research needs for meeting the challenge of decentralized energy supply in developing countries. Energy Sustain Dev 2011;15(3):324–9.

Schmidt TS, Dabur S. Explaining the diffusion of biogas in India — a new functional approach considering national borders and technology transfer. Environ Econ Policy Stud 2013:1–29.

Schmidt TS, Born R, Schneider M. Assessing the costs of photovoltaic and wind power in six developing countries. Nat Clim Change 2012;2:548–53.

Schneider M, Schmidt TS, Hoffmann VH. Performance of renewable energy technologies under the CDM. Clim Policy 2010;10(1):17–37.

Senoaji. Rencana dan Strategi PLN dalam Penyediaan PV. Workshop Peran PV Dalam Penyediaan Energi Listrik Di Indonesia 2008. [Presentation].

Sovacool BK, Valentine SV. Bending bamboo: restructuring rural electrification in Sarawak, Malaysia. Energy Sustain Dev 2011;15(3):240–53.

Sovacool BK, Bambawale MJ, Gippner O, Dhakal S. Electrification in the Mountain Kingdom: the implications of the Nepal Power Development Project (NPDP). Energy Sustain Dev 2011a;15(3):254–65.

Sovacool BK, D'Agostino AL, Bambawale MJ. Gers gone wired: lessons from the renewable energy and rural electricity access project (REAP) in Mongolia. Energy Sustain Dev 2011b;15(1):32–40.

Takada M, Charles NA. Energizing poverty reduction — a review of the energy-poverty nexus. Poverty reduction strategy papers. New York, USA: UNDP (United Nations Development Programme) 2007.

Terrado E, Cabraal A, Mukherjee I. Operational guidance for World Bank group staff designing sustainable off-grid rural electrification projects: principles and practices. Washington D.C., USA: The World Bank/The Energy and Mining Sector Board; 2008.

The CIA World Factbook. Indonesia's geography. Available at:https://www.cia.gov/library/ publications/the-world-factbook/geos/id.html, 2013. [Accessed February 11, 2013].

The Gold Standard Foundation. The Gold Standard requirements version 2.2, Geneva, Switzerland; 2012.

The Pew Charitable Trusts. Who's winning the clean energy race?, Philadelphia and Washington, D.C., USA; 2011.

The World Bank. Doing business 2013 — smarter regulations for small and medium-size enterprises 10th ed. Washington, D.C., USA: World Bank Group; 2013.

Transparency International. Corruption perceptions index ranking. Available at: http://www.transparency.org/cpi2012/results, 2013. [Accessed February 27, 2013].

UN AGECC. Energy for a sustainable future: summary report and recommendations. New York, USA: UN (United Nations)/The Secretary-General's Advisory Group on Energy and Climate Change; 2010.

UNDP. Towards an " Energy Plus " approach for the poor, Bangkok, Thailand; 2011.

UNEP. In: UNEP (United Nations Environment Programme), editor. REED toolkit a handbook for energy entrepreneurs. Bloomfield, USA: UN Foundation and E + Co 2005.

UNEP. Reforming energy subsidies — opportunities to contribute to the climate change agenda. United Nations Environment Programme (UNEP) 2008.

UNEP. Financing renewable energy in developing countries: drivers and barriers for private finance in Sub-Saharan Africa, Geneva, Switzerland; 2012.

UNESCO. UNESCO Data Centre. Available at:http://stats.uis.unesco.org/unesco/TableViewer/ document.aspx?ReportId=136&IF_Language=eng&BR_Topic=0, 2009. [Accessed December 19, 2012].

UNFCCC. Draft revision to the guidelines on the assessment of investment analysis (version 04). United Nations framework convention on climate change (UNFCCC) 2010.

Van Mansvelt R. The solar roadmap for Cambodia — how to scale-up solar diffusion in Cambodia? Strategy formulated by stakeholders. Phnom Penh, Cambodia: Pico Sol Cambodia; 2011.

Von Hippel E. Democratizing innovation, Cambridge, Massachusetts; London. England: The MIT Press; 2005.

Waissbein O, Glemarec Y, Bayraktar H, Schmidt TS. Derisking renewable energy investments. New York, USA: United Nations Development Programme (UNDP); 2013.

White H, Blöndal N, Rota M, Vajja A. The welfare impact of rural electrification: a reassessment of the costs and benefits. Washington, D.C., USA: The World Bank and Independent Evaluation Group; 2008.

Winoto AT, Marliska ED, Prasetyo MH, Simangunsong S. Rural electrification in Indonesia target and development; 2012 [Presentation].

Yadoo A. Delivery models for decentralised rural electrification: case studies in Nepal, Peru and Kenya. London: International Institute for Environment and Development; 2012.

Yadoo A, Cruickshank H. The value of cooperatives in rural electrification. Energy Policy 2010;38(6):2941–7.

Yadoo A, Cruickshank H. The role for low carbon electrification technologies in poverty reduction and climate change strategies: a focus on renewable energy mini-grids with case studies in Nepal, Peru and Kenya. Energy Policy 2012;42:591–602.

Yin RK. Case study research — design and methods. 3rd ed. Thousand Oaks, USA; London, UK; New Delhi, India: Sage Publications; 2003.

Yumkella KK, Srivastava L. Energy fo All. Making it Magazine. Available at:http://www. makingitmagazine.net/?p=655, 2010.

Zerriffi H. Rural electrification: strategies for distributed generation. Dordrecht, Heidelberg, Germany; London, UK; New York, USA: Springer; 2011.