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Accelerating the Energy Transition through Power Purchase Agreement Design: A Philippines Off-Grid Case Study

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Abstract: As renewable energy (RE) costs decrease, private non-subsidized revenue sources, such as power purchase agreements (PPA), will increase in off-grid areas. This paper's objective is to improve policymakers' and utilities' understanding of PPA's role in mitigating private investors' risks in off-grid areas to accelerate the energy transition. The paper built a PPA dataset for the largest off-grid area in the Philippines and developed novel and efficient techniques to evaluate the risk mitigation ability of a PPA. While oil-based technologies are expensive, they are low-capital-intensive, and the fuel, the bulk of the cost, is passed through to consumers and primarily funded by subsidies. In contrast, the most affordable energy source, RE, requires higher upfront capital investments, financed primarily with equity. Investors chose low-capital-intensive technologies (oil), rehabilitated power plants, and utilized old equipment, all investment decisions to mitigate residual PPA risks, i.e., distribution utilities' low creditworthiness and capital recovery uncertainty. Presenting the investment as a PPA residual mitigation tool is one of the paper's contributions to the literature. The distribution utility needs to reduce investors' uncertainty by covering reasonable investors' costs. Policymakers need to level the playing field between fossil fuels and RE by reducing subsidies and strengthening distribution utility creditworthiness.

Keywords: power purchase agreement; PPA; risk management; off-grid; investment; renewable energy; energy transition; subsidy; fossil fuel

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1. Introduction

Financing a high-capital-intensive business such as electricity generation is closely linked to risk mitigation [1]. To mitigate revenue risks, investors strive to secure long-term revenue contracts [2,3], such as power purchase agreements (PPAs), with creditworthy parties [4]. A PPA is a contract between the buyer (e.g., a distribution utility or a corporation) and the seller of electricity (a power project) containing the key terms and conditions of the agreement. A PPA requires careful design to secure financing [5]. A project might be economically viable because expected revenues are higher than expected costs but not financeable because it lacks contractual guarantees to pay back investors [6]. An adequately designed PPA can provide most of these guarantees.

Investors have used long-term revenue contracts, such as PPAs, for decades. An example is feed-in tariff (FIT) contracts between renewable energy (RE) projects and the government or the regulatory authority, whereby RE projects receive a fixed price per kWh for 15 to 20 years [7]. Over the last decade, PPAs have played a more prominent role as government incentives, such as feed-in tariffs, were discontinued and RE technologies became cost-competitive. For example, in 2022, companies signed 36.7 GW of RE PPAs, up 18% from 2021 [8], mainly wind and solar, virtually all on-grid. PPAs have played a far less crucial role in off-grid areas, areas not connected to the main grid, due to the high energy cost, requiring heavy government subsidies and assistance. This situation will change as RE and batteries become cost-competitive and governments reduce and discontinue subsidies.

RE penetration in off-grid areas often lags on-grid. In 2021, just 8% of the off-grid power capacity in the Philippines was RE [9], compared with on-grid at 29% [10]. Palawan Island in the Philippines, the focus of this article, makes an excellent international case study since, despite being an off-grid area with its typical limitations (e.g., remoteness, low purchasing power, limited infrastructure), its large size and growth should have enabled affordable renewable energy solutions. Instead, its RE penetration is virtually non-existent, and its electricity is expensive, dirty, and unreliable. Palawan Island's population, area, and length are 0.994 million, 12,188 km^2, and 425 km, respectively. Palawan's economy grew by an average of 5.7% per year between 2000 and 2019. Worldwide, around 733 million people, accounting for about 10% of the population, live without access to electricity [11], accounting for the most economically disadvantaged and underserved segment of the population. In the Philippines, an archipelagic country with 7641 islands, around 7% of the population resides in off-grid areas [12]. Off-grid PPA design is challenging due to high credit risk (often single buyer), subsidy distortions, power projects' sub-optimal scale, and high cost. These challenges disadvantage RE relative to fossil fuels since RE is often intermittent and variable, tends to be more capital-intensive, and is more subject to economies of scale. Due to these challenges, a power purchase agreement (PPA) design becomes crucial in enabling the energy transition in off-grid areas. When a PPA is appropriately designed, it can instill confidence in RE investors, streamline the deployment of renewable energy, and ensure the delivery of clean and affordable energy to the community.

Several reputable articles have focused on PPA design but typically on very particular terms or conditions [13–21]. Over the last few years, the PPA literature has concentrated on RE or Green PPAs [5,22–29]. The literature on off-grid PPAs is far sparser and often focused on particular terms or revenue solutions [30–34]. To our knowledge, this paper is the only one to comprehensively analyze off-grid PPA design by evaluating over a dozen off-grid PPA terms and conditions and assessing their risk mitigation ability. Other contributions to the literature are the paper's holistic perspective of the investment process, from detailed PPA investment drivers to energy outcomes, the development of innovative techniques to evaluate PPA risks, and the presentation of the investment itself as a risk mitigation tool instead of just the PPA.

This paper aims to inform policymakers and distribution utilities on designing off-grid PPAs to secure investments and enable seamless transitions to clean, affordable, and reliable energy sources. It also informs investors on how to mitigate PPA risks. The paper hypothesizes that (a) PPA contract design is a significant factor impacting off-grid investment decisions, and (b) poor PPA design can bias investments toward low-capital intensive fossil fuel technologies.

The balance of the paper covers background (Section 2), investment drivers and investors' decisions (Section 3), data and methodology (Section 4), results (Section 5), discussion (Section 6), conclusions (Section 7), and policy recommendations (Section 8).

2. Background

In off-grid areas, private companies generate and sell electricity to distribution utilities (DU), primarily electric cooperatives, under power purchase agreements (PPA) subject to price regulation. In on-grid areas, for-profit private distribution utilities account for most of the load. In contrast, in off-grid areas, distribution utilities are primarily electric cooperatives, i.e., non-profit organizations owned by their electricity end-users. Palawan Electric Cooperative (Paleco) is the distribution utility of Palawan Island, with a franchise area composed of several isolated grids. Power generation was supplied in the early 2000s by the National Power Corporation (NPC), a government-owned company. However, after the EPIRA (Electric Power Industry Reform Act) law approval in 2001 mandating the privatization of NPC's assets, Paleco is currently supplied primarily by private companies. NPC is the supplier of last resort for both generation and distribution services in off-grid areas. NPC subsidizes off-grid areas by paying private generation companies the difference between their generation cost, TCGR (true cost generation rate), and the subsidized rate,

SAGR (subsidized approved generation rate), through a subsidy agreement. Distribution utilities only pay the SAGR to generation companies, which is considerably lower than the TCGR. A universal charge for missionary electrification paid by all electricity consumers in the Philippines funds this NPC subsidy. Traditional RE incentives (e.g., feed-in-tariffs (FITs)) were not in effect in off-grid areas during the period of the study (2000–2020). In theory, a cash generation-based incentive is available for off-grid RE projects. However, the subsidy is uncertain, and the amount is variable; consequently, this subsidy was not included in the analysis. The Department of Energy (DOE) oversees the energy policy, the Energy Regulatory Commission (ERC) is the regulator approving power purchase agreements (PPA) and respective subsidy agreements (SA), and the National Electrification Administration (NEA) oversees electric cooperatives.

3. Investment Drivers and Investors' Decisions

Investors decide if and how much capital to invest in a project on the basis of its return and risk profile [1]. The PPA is a critical risk mitigation mechanism [35–37]. Key PPA terms and conditions and respective ability to mitigate risks drive investment decisions. Consequently, the paper refers to these key PPA terms and conditions as PPA investment drivers. Each PPA investment driver mitigates a corresponding risk. For example, the purpose of the fuel fee is to mitigate the risk of the fuel price increase by designing the fuel fee as a pass-through. If the fuel cost is pass-through, the investor is incurring the cost on behalf of the energy buyer (Paleco). The investor initially pays for the fuel cost but bills it to the energy buyer (Paleco). The purpose of buying commitments is to avoid potential energy/power buying shortfalls.

The subsections below describe the PPA investment drivers, resulting in investment decisions and energy outcomes. Figure 1 lists them in a logical flow. For example, a short contract term and lack of buying commitments (PPA investment drivers) might result in a no-invest decision or re-use of old oil-based power equipment (investment decisions), which could translate into a lack of power or expensive and polluting electricity (energy outcomes). Figure 1 also groups the PPA drivers and investment decisions into logical categories. For PPA drivers, these categories are contract parties, rate (price), volume, product, contract period, and location. Figure 1 provides a structured and holistic perspective of the investment process from start (drivers) to finish (energy outcomes), and it is one of the contributions of this paper to the body of knowledge.

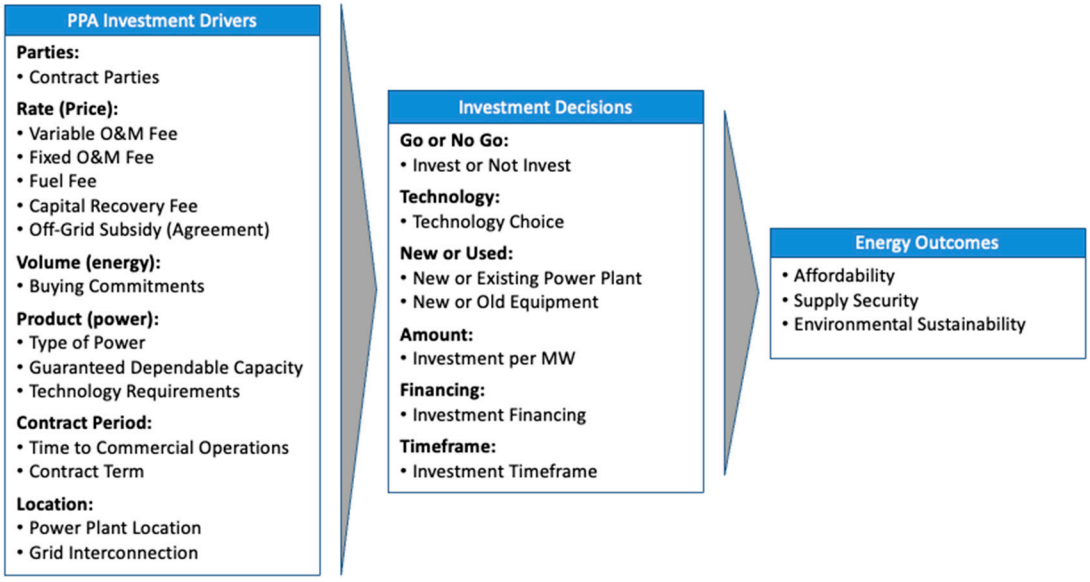

Figure 1. Investment drivers, investment decisions, and energy outcomes.

3.1. PPA Investment Drivers

The investor aims to sign an adequately designed PPA to minimize risk and equity requirements and secure affordable debt financing. This section focuses on the most common PPA investment drivers in the PPA ERC applications [38,39]. Table 1 provides each PPA investment driver's definition, ideal investors' design, and reputable literature citations. Several of these drivers have been individually researched, but this paper contributes to the body of knowledge by evaluating their risk profiles, combining them, and assessing their impact on the investment decision.

Table 1. PPA investment drivers, definitions, ideal structure for investors, and references.

PPA Investment Driver	Definition	Ideal Design for Investors	References
Parties:			
Contract parties	PPA signatory parties; buyer and seller	Creditworthy and experienced parties	[5,33,36]
Rate (Price):			
Variable O&M fee	Fee to recover O&M that varies with the energy generated	Php per kWh	[5]
Fixed O&M fee	Fee to recover O&M that does not vary with the energy generated	Php per kW per month	[17]
Fuel fee	Fee to recover fuel costs	Pass-through	[13,18]
Capital recovery fee	Fee to recover capital costs (repayment and fair return)	Php per kW per month; Low requirement level	[13,16,18,40]
Off-grid subsidy	Subsidy in excess of the subsidized generation rate	Regulator-approved and flexible to cover TCGR	[41]
Volume:			
Buying commitments	Minimum energy (kWh) or power (kW) buying commitments	Minimum commitments or priority dispatch	[21,22,26]
Product:			
Type of power	Baseload, mid-merit, or peak power	Flexible firm requirements	[18,42]
GDC	Minimum capacity (kW) available at all times	Flexible firm requirements	[24,26]
Technology requirements	Excluded technologies	Allowed technologies match developer capabilities	[43,44]
Contract Period:			
Time to COD	The time between PPA effectivity and commercial operations date	Sufficient to construct the power plant	[6,22]
Contract term	PPA duration (years)	The longer, the better; ≥10 years to recoup capital investment	[14,16,20,27,36]
Location:			
Plant location	Power plant location requirements	Near load	[31,34]
Grid interconnection	Interconnection requirements (LV, HV)	Near interconnection	[30,31,45]

The financial and technical capacity of the contract parties, i.e., the buyer (Paleco) and the seller (investor), are vital in obtaining financing. The buyer's creditworthiness [46,47] is critical, especially in off-grid areas where the buyer might be the only one available and consumers have limited buying power [48,49]. EC's creditworthiness can be a major investor concern [50].

Capital recovery fees (CRFs) allow investors to recover their capital investment with a reasonable return. With high uncertainty, investors prefer low capital requirements to minimize capital exposure and fixed fees to mitigate energy generation shortfalls [44,46].

3.2. Investment Decisions

Given the investment drivers, the investor will make a series of interrelated investment decisions described below. These investment decisions can also be interpreted as a way to mitigate further the residual risk left on the PPA. This section describes the most common investment decisions based on investors' audited financial statements [51], DOE's list of off-grid power plants [9], and PPA ERC applications (Supplementary Materials).

Invest or not invest: The investors' most basic decision is to invest or not [13,35,52]. Not investing is the ultimate risk mitigation decision since it eliminates all risk but also any return.

Technology choice: Investors choose the fossil fuel or RE technology that best meets the PPA requirements, given their capital constraints, capabilities, motivation, and risk appetite. Hedges and Duvoort [15] showed that technology choices impact the project investment risk.

New or existing power plant: It is easier for investors to fund the rehabilitation or refurbishment of an existing power plant than to develop and construct a new one due to existing infrastructure, permits, land, and lower capital expenditures [18]. This provides an advantage to existing installed technologies such as diesel and HFO.

New or old equipment: Capex requirements for used equipment are lower than for brand-new equipment, but reliability might be lower. Old equipment refers to pre-owned, used, or second-hand equipment [53].

Actual investment per MW: A higher investment per MW reflects a higher capital at risk. Technologies with a low investment per MW minimize upfront investment [6,34]. Major determinants of the actual investment per MW are technology choice and new or old equipment/power plant.

Investment long-term financing: These options include long-term capital in equity or long-term debt. A higher risk leads to a lower bank debt share in financing [47] due to its lower risk tolerance. Long-term debt is difficult to obtain in off-grid areas [32]. A bankable PPA is critical [5,33,53].

Investment timeframe: This is the time elapsed between PPA signing and commercial operations. The investor may delay the investment until it can mitigate critical risks.

These investment decisions include rarely researched ones, such as new or existing power plants and new or old equipment, which are highly relevant for developing economies with limited financial resources or off-grid areas with limited risk mitigation options.

Investors' decisions will determine energy outcomes (affordability, supply security, and environmental sustainability), often seen as an energy trilemma due to their trade-offs. The paper's main purpose is not to analyze energy outcomes, but these flow from the investment decisions; hence, this paper describes them. The energy outcomes align with UN Sustainable Development Goal 7 [54]: "Ensure access to affordable, reliable, sustainable, and modern energy for all". Energy affordability is the actual cost of the energy, the TCGR. Energy security is the capacity of the power supply to meet current and future energy demand reliably, and it can be measured as the supply capacity in MW versus demand. The number of power plant outages can measure reliability. The RE share in the energy mix is a proxy for environmental sustainability.

4. Materials and Methods

4.1. Data

The paper created a novel dataset, off-grid dataset (Supplementary Materials), consisting of more than 50 detailed records for each of the eight PPAs Paleco signed between 2000 and 2020. Each record consists primarily of investment drivers and resulting investment decisions, and secondarily of identifiers and other data. Table 2 presents the eight PPAs that Paleco signed during the period. The four investors, the power generation companies, are Palawan Power Generation, Inc. (PPGI), Delta P, Inc. (DPI), DMCI Power Corporation (DPC), and Langogan Power Corp. (LPC), with two, two, three, and one PPAs, respectively.

Table 2. PPA summary.

PPA	PPGI 2009	PPGI 2010	DPI 2009	DPC 2012	DPC 2013	DPC 2017	DPI 2017	LPC 2016
Technology	Diesel/HFO	Diesel/HFO	HFO	Diesel	Diesel/Coal	HFO	HFO	Hydro
Capacity—MW	7.2	10.0	16.0	5.0	27.0	9.9	30.3	17.8

Source: Off-grid dataset (Supplementary Materials). Note: The PPA name includes investor name plus commercial operation date (COD) or date filed with the Regulator if no COD occurred.

The primary data source for the PPA investment drivers was the PPA applications with the regulator and the investor's audited financial statements. Data sources for investors' decisions were, primarily, the investors' audited financial statements and, secondarily, PPA applications with the regulator and DOE's list of power plants in off-grid areas. Table 3 summarizes the main data sources per investment driver and investor's decisions.

Table 3. Main data sources for investment drivers and investor's decisions.

Main Data Source	Investment Drivers and Investor's Decisions
PPA ERC applications	PPA investment drivers: contract parties, contract term, variable cost operations and maintenance fee (VOM), fixed operations and maintenance fee (FOM), fuel fee, capital recovery fee (CRF), buying commitments, guaranteed dependable capacity (GDC), technology requirements, time to commercial operations date (COD), type of power, power plant location, grid interconnection location, off-grid subsidy agreement; Investment decisions: technology choice, new or existing power plant, new or old equipment, investment per MW, energy outcomes
Investor's audited financial statements	PPA investment drivers: time to commercial operations date (COD); Investment decisions: invest or not invest, long-term financing, technology choice, new or existing power plant, new or old equipment, investment per MW, energy outcomes
DOE's list of off-grid power plants	PPA investment drivers: power plant location Investment decisions: invest or not invest, technology choice, new or existing power plant.

The paper also used the off-grid dataset and financial data on the ERC PPA applications to build representative financial models, model and sensitivity analysis worksheet (Supplementary Materials), for each of the four off-grid technologies (diesel, heavy fuel oil, small coal, and hydropower) included in Paleco's ERC PPA applications. The paper added a solar financial model, given the potential for this technology in off-grid areas. Most solar data were sourced from ERC's 2017-012 RC Order approving a PPA on solar in Luzon Island [55]. The financial models indicate in detail the data source for each variable. The paper converted original Philippine pesos values into US dollars for easier reading.

4.2. Methodology

The paper followed a multi-step methodology, summarized in Figure 2.

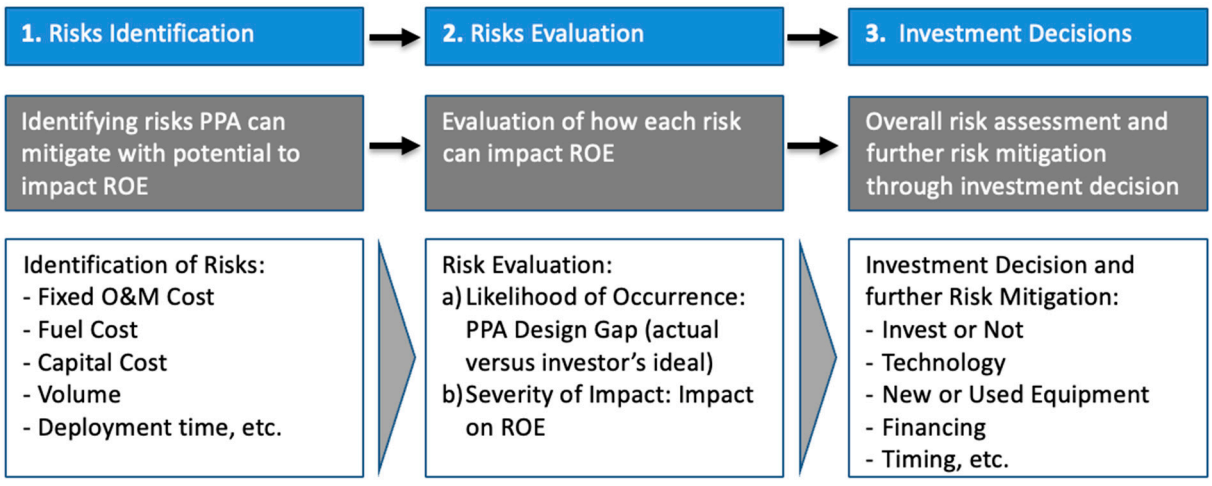

Figure 2. Research methodology flowchart description.

First, the paper identified risks that each PPA investment driver could mitigate. Risks are possible outcomes that negatively impact investors' return on equity (ROE). The paper accomplishes this in Section 4.2.1. For example, the fuel cost (PPA risk) can negatively impact ROE if the fuel fee (PPA investment driver) is not pass-through.

Second, the paper evaluated the magnitude of each risk, which is a function of the likelihood of occurrence and severity of impact if the risk occurs. In the literature, risk

magnitude equals the likelihood of occurrence times severity of impact [56]; hence, the risk is a function of the following:

(a) The likelihood of occurrence is the likelihood of impacting the investor's ROE, which is a function of the actual PPA design versus investors' ideal. For example, if the fuel fee is pass-through to consumers (investor's ideal), the likelihood that changes in fuel prices will impact ROE is low;

(b) The severity of impact or consequence of occurrence if the risk occurs is the extent to which the risk can impact investors' ROE. For example, higher fuel prices can erase investors' ROE if fossil fuel costs are not passed through. The paper evaluates risk severity impact by building a representative financial model for each key generation technology, conducting a sensitivity analysis of the risks, and measuring the effect on the ROE.

Once each risk is classified by likelihood of occurrence and severity of impact, they can all be mapped in a risk matrix, as shown in Figure 3. This can also be achieved using a table for easier comparison amongst PPAs. More risks in the upper right corner of the matrix (extreme or high risks) denote higher chances of no investment. The investor would strive to design the PPA such that all risks are in the lower left corner (low risks).

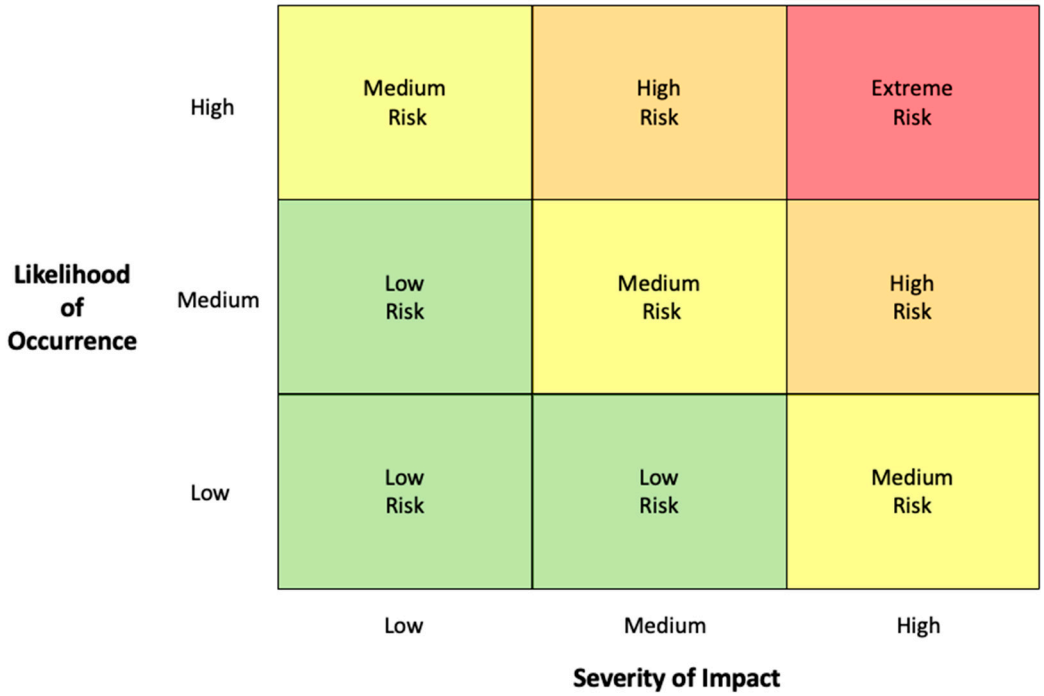

Figure 3. Risk evaluation matrix (likelihood of occurrence and severity of impact).

Third, the paper assessed the overall risk of the PPA (combined individual risks) and explained the respective investor's decisions. These investment decisions can be interpreted as further risk mitigation measures if the PPA design did not mitigate key risks. For example, a no-investment decision is the ultimate risk mitigation measure. On the other hand, the investor might proceed with the investment but choose a low-capital-intensive technology (diesel) and reduce further capital by opting for used equipment.

If this methodology reasonably explains the investor's decisions, the paper affirms the initial hypothesis that PPA contract design significantly impacts off-grid investment decisions.

The broad strokes of the methodology described in Figure 2 are similar to a typical risk management methodology consisting of risk identification, evaluation, and mitigation. However, it contains several key differences and contributions to the literature. First, while the PPA in a typical risk management exercise could be the risk mitigation tool, i.e., the result of the risk identification and evaluation, in the case of this paper, the investment

itself is the key risk mitigation tool. Second, the paper evaluates PPA risks using innovative methods: the PPA design gap versus the investors' ideal to calculate the likelihood of occurrence and an annuity formula to calculate the severity of impact.

4.2.1. Identification of Risk PPA Mitigates (PPA Risks)

Table 4 describes the risks the PPA aims to mitigate by matching each investment driver (key PPA terms and conditions) presented in Section 3.1 with the risk it intends to mitigate. For example, the PPA can mitigate the fixed O&M cost risk by setting the fixed O&M fee at a level that covers the fixed O&M costs and making it a flat fee that does not vary with the energy generated. The paper keeps the risk name similar to the respective investment driver for easy reading.

Table 4. PPA investment drivers, risks PPA mitigates (PPA risk), and respective risk definition.

PPA Investment Driver	Risk PPA Mitigates	Risk Definition
Parties:		
Contract parties	Creditworthiness	Contract parties default on obligations
Rate (Price):		
Variable O&M fee	Variable O&M cost	Variable O&M cost > Variable O&M fee
Fixed O&M fee	Fixed O&M cost	Fixed O&M cost > Fixed O&M fee
Fuel fee	Fuel cost	Fuel cost > fuel fee
Capital recovery fee	Capital cost	Capital costs > capital recovery fee
Off-grid subsidy	Off-grid subsidy	TCGR > SAGR
Volume:		
Buying commitments	Volume	Actual volume < forecasted volume
Product:		
Type of power	Type of Power	Mismatch between power required and offered
GDC	GDC	Mismatch between capacity required and offered
Technology requirements	Technology exclusions	Excluded technology
Contract period:		
Time to COD	Deployment time	Time to COD < deployment time
Contract term	Contract term	Short contract duration
Location:		
Plant location	Plant location	Distant from load
Grid interconnection	Grid interconnection	Lack or insufficient grid connection

4.2.2. Risk Likelihood Evaluation Methodology

In Section 5.1, the paper evaluates the likelihood of each risk impacting ROE (low, medium, and high) by comparing its actual design with the investor's ideal. Table 1 in Section 3.1 describes the ideal design for investors. For example, if the fuel fee (PPA driver) is structured as a fuel cost pass-through to Paleco, the investor's ideal, the likelihood that fuel cost (risk) will impact the investor's ROE is low. On the other hand, if the fuel fee is a fixed rate, there is a high likelihood that fuel cost will impact investors' ROE due to fuel price volatility. Most risks are unlikely to occur if the PPA is designed according to the investor's ideal.

4.2.3. Risk Severity of Impact Evaluation Methodology

In Section 5.2, the paper conducts an ROE sensitivity analysis to measure the severity of the impact of each PPA risk. The first step was to build financial models representative of each off-grid generation technology based on information retrieved from the ERC PPA applications. Table A1 contains the assumptions and details for the financial model of off-grid technologies. The second step was to vary each identified PPA risk and measure the impact on the ROE.

If actual outcomes match expectations, ROE will be equal to the cost of equity. This means that O&M revenues (fees) will match O&M costs, fuel revenues (fees) will match fuel costs, and capital recovery revenues (fees) will match capital costs. However, if this does not happen, the ROE will differ from the cost of the equity. In this case, the actual

ROE might be lower than the cost of equity, which might result in a no-investment decision. Figure 4 describes some reasons why this might happen.

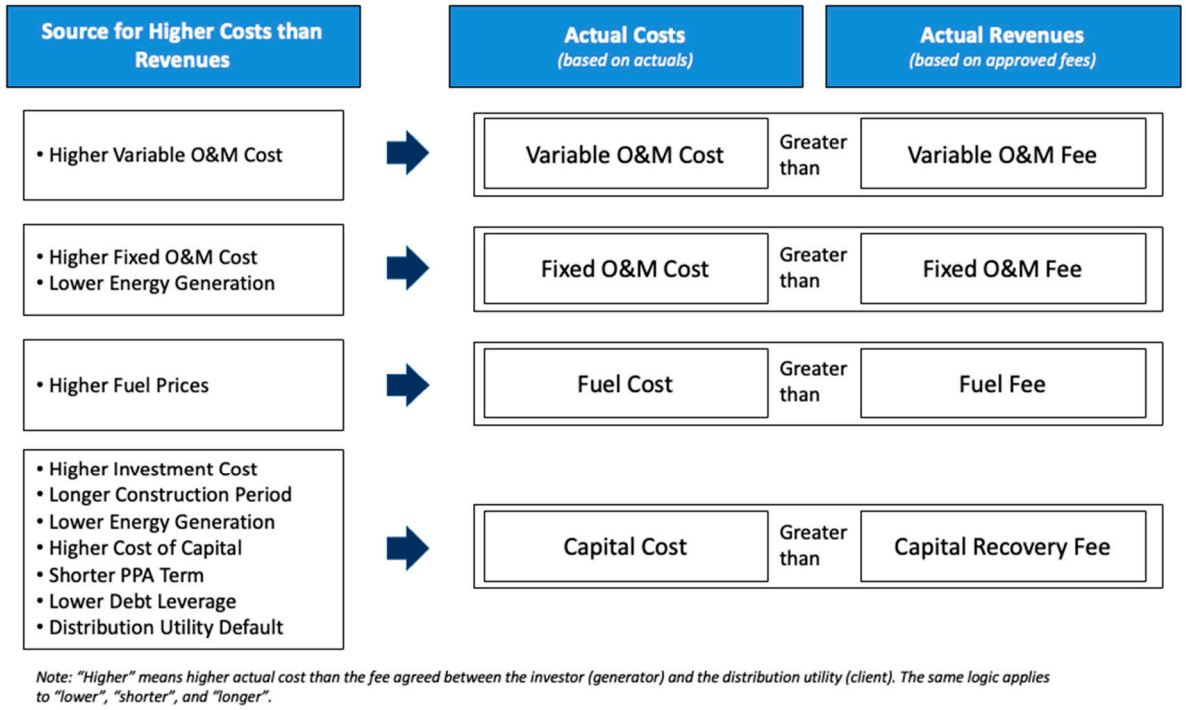

Figure 4. Factors that result in a lower ROE than the cost of equity.

The methodology to determine the actual ROE is the following:

The actual ROE is a function of four factors: (a) annual cash flows to capital (actual annual capital recovery); (b) the actual investment cost; (c) the investment useful life; (d) capital structure and cost. The paragraphs below describe the calculations in detail.

1. Actual annual capital recovery = actual revenues − actual operating costs

The paper calculates the actual annual capital recovery by default: actual revenues (based on approved fees) minus actual operating costs (based on actual costs). After paying fuel suppliers and O&M, whatever is left constitutes the annual cash flow to capital holders. The actual revenues are equal to the approved rate (TCGR) times the actual energy delivered. Appendix B explains the TCGR calculation.

Actual revenues (Php) = TCGR (Php/kWh) × actual energy delivered (kWh) = [fuel rate + variable O&M rate + fixed O&M rate + capital recovery rate] × actual energy delivered (kWh)

Actual operating costs (Php) = actual fuel costs (Php) + actual variable O&M costs (Php) + actual fixed O&M costs (Php)

2. Actual investment = civil works + electromechanics + project development + installation + construction insurance + interests during construction + others
3. Actual capital return pre-tax (%) = RATE (investment useful life (years), − actual investment (Php), actual annual capital recovery (Php))

The paper calculates the actual capital return pre-tax using an annuity formula, i.e., it assumes the same actual annual capital recovery for the investment's useful life. The ERC uses the same methodology, which is simple, straightforward, and accepted by investors in the Philippines. Even if ERC were not involved in approving rates, investors would need to follow a similar approach to calculate their ROE.

The RATE function in Excel calculates the actual capital return (r) as follows: actual annual capital recovery (Php) = $\frac{r}{1-(1+r)^{-n}}$ × actual investment (Php), where r is the actual capital return pre-tax, and n is the investment useful life in years.

4. The actual ROE is calculated by default, given the capital structure and cost, using the following formula:

$$r = \frac{\text{debt}}{\text{capital}} \times \text{cost of debt} + \frac{\text{equity}}{\text{capital}} \times \text{ROE}/(1 - \text{taxrate})$$

where capital is the actual investment.

Please note that the r is pre-tax and not after-tax since it calculates the capital recovery rate that will still be subject to income tax, as shown below:

$$\text{Capital return after tax } (\%) = \frac{\text{debt}}{\text{capital}} \times \text{cost of debt} \times (1 - \text{tax rate}) + \frac{\text{equity}}{\text{capital}} \times \text{ROE};$$

$$\text{Capital return pre-tax } (\%) = \text{capital return after tax } (\%)/(1 - \text{tax rate}) = \frac{\text{debt}}{\text{capital}} \times \text{cost of debt} + \frac{\text{equity}}{\text{capital}} \times \text{ROE}/(1 - \text{taxrate})).$$

Figure 5 summarizes the actual ROE calculation process. The ROE calculation method outlined in Figure 5 is innovative and time-saving in comparison to the process of creating extensive multi-year financial statements. Despite the ERC's usage of this annuity method to compute capital fees, its application for assessing the PPA risk's impact on the ROE has not been observed in the existing literature.

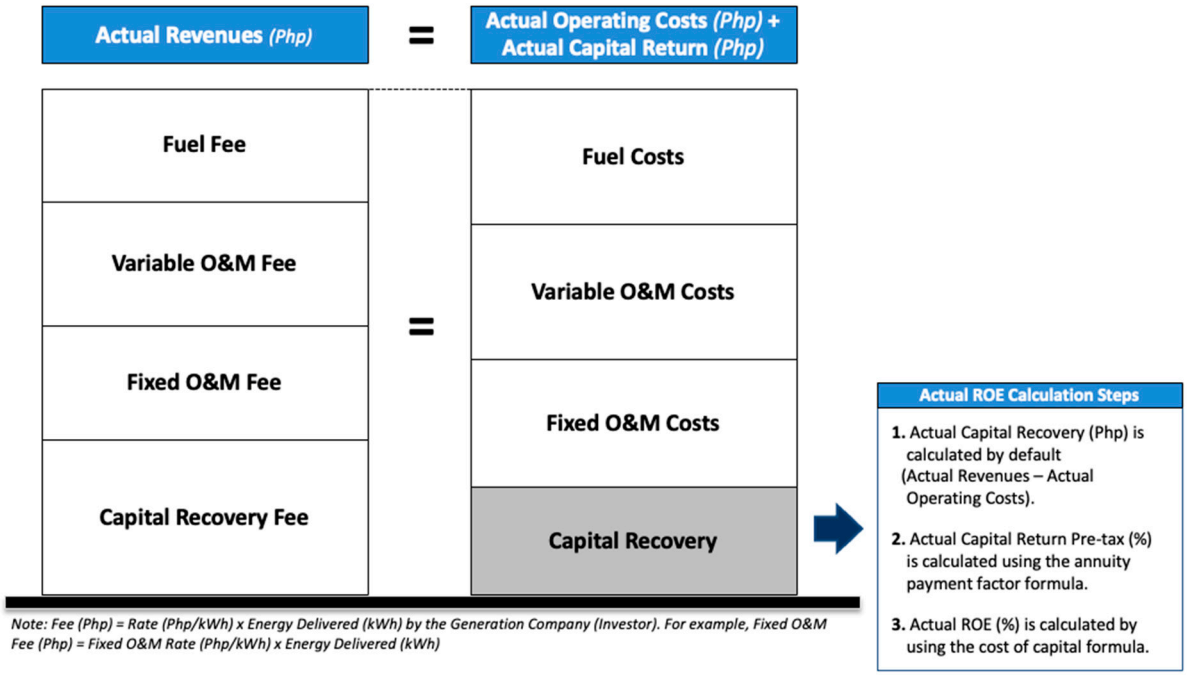

Figure 5. Actual return on equity (ROE) calculation.

4.2.4. Investment Decisions

Section 5.3 describes the resulting investment decisions given the risks' likelihood of occurrence and severity of impact if they occur. The investment decision, itself, can be a risk mitigation exercise if critical PPA risks were not mitigated.

5. Results

5.1. Evaluation of Risks' Likelihood of Occurrence

The risk likelihood evaluation is based on analyzing the PPA investment drivers' contractual design. If the actual PPA design meets investors' requirements, then the likelihood of the risk occurring is low. For example, if the fuel cost is pass-through to consumers (investor's ideal), then increases in fuel prices are unlikely to impact investors' ROE.

Table 5 summarizes the contract design gap results. The cells shaded in dark gold (gold stands for wealth) indicate an ideal contractual design from the investor's perspective, while no shade indicates a risky contractual design.

Table 5. Risks' likelihood of occurrence (PPA investment drivers' design gap).

PPA	PPGI 2009	PPGI 2010	DPI 2009	DPC 2012	DPC 2013	DPC 2017	DPI 2017	LPC 2016
Technology	Diesel/HFO	Diesel/HFO	HFO	Diesel	Coal/Diesel	HFO	HFO	Hydro
Capacity—MW	7.2	10.0	16.0	5.0	27.0	9.9	30.3	17.8
PPA Investment Drivers:								
Contract parties	PPGI/Paleco	PPGI/Paleco	DPI/Paleco	DPC /Paleco	DPC /Paleco	DPC /Paleco	DPI /Paleco	LPC/Paleco
Variable O&M fee	/kWh	/kWh	/kWh	/kWh	/kWh	/kWh	/kWh	/kWh
Fixed O&M fee	/kWh	/kWh	/kWh	n/a	/kWh	/kWh	/kW/mo.	/kWh
Fuel fee	Pass-through	Pass-through	Pass-through	Pass-through	Pass-through	Pass-through	Pass-through	n/a
Capital recovery fee	/kWh	/kWh	/kWh	/kW/mo.	/kWh	/kWh	/kW/mo.	/kWh
Capital recovery fee (level) [1]	Low	Low	Low	Low	C: High D: Low	Medium	Medium	Very High
Off-grid subsidy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Buying commitments	None	None	None	None	None	None	None	None
Priority dispatch	Yes	2nd	3rd	4th	4th	4th	Merit order	Yes
Type of power	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Non-Firm
GDC	None	None	13.5	5.0	25.0	9.9	20.0	None
Time to COD [2] (months)	n/a	n/a	2	2	13	6	12	30
Contract term (years)	15	15	10	1	15	12	15	25
Plant location	City	Suburb	City	City	Suburb	Suburb	City	Rural
Grid interconnection	LV	HV	LV	LV	HV	HV	LV/HV	HV

TABLE LEGEND: *Ideal contract design for Investors*; *Tolerable contract design for investors*; *Risky/problematic design for investors*

Source: Off-grid dataset (Supplementary Materials). [1] *Capital recovery fee level required (based on planned upfront investment) as indicated in the PPA application to ERC.* [2] *Commercial operations date: from PPA signing (DPI 2009, DPC 2012, DPC 2013); from regulator approval (DPC 2017, DPI 2017, LPC 2016). Note: "D" stands for diesel, and "C" stands for coal. HV: high voltage; LV: low voltage.*

Contract parties: Paleco, the buyer, is the only distribution utility in Palawan Island, with its franchise area covering most of the island. Paleco is an electric cooperative (EC) owned by its member-consumers with a franchise area containing 250,781 households, of which only half are electrified [57]. According to NEA, which tracks the performance of ECs, Paleco is a mega large (the largest size classification) EC, with an overall A rating (ECs ratings are AAA, AA, A, B, C, and D) [58]; thus, it is not ideal for investors.

DPC is owned by a publicly listed company with a core business in coal mining and power, and it is one of the largest conglomerates in the Philippines. Hence, DPC enjoys a solid financial and technical background. It is a similar case to DPI since its shareholders are power companies, and one of them, Vivant Energy Corporation, is a publicly listed company. Power One Corporation (POC), the minority shareholder of PPGI, signed the PPAs with Paleco in 2004 but seemed only to have secured financial resources in 2007 when PPGI was incorporated with FLG Management & Development Corporation as the majority shareholder. LPC is an independent British–Filipino developer focused on hydropower in Palawan. Its financial capacity seems limited since the bulk of its capital constitutes consulting services provided by shareholders, and the 2019 financial statements auditor points to a net capital deficiency. LPC's technical capacity seems to reside with its shareholders.

Variable operations and maintenance fee: In all PPAs, the investors recover the variable operations and maintenance (O&M) cost through a fixed rate per kWh, allowing investors to recoup their variable O&M costs as energy generation increases.

Fixed operations and maintenance fee: Investors prefer a fee structure that allows them to recoup these fixed expenses regardless of the energy generated. In six out of eight

PPAs, investors recover fixed costs on a kWh basis. The exception is DPI 2017, where cost recovery is a fixed amount per month (per kW/month), which is ideal for investors.

Fuel fee: The fuel cost is pass-through, subject to a fuel efficiency cap for all fossil fuel PPAs (seven out of eight PPAs), limiting investors' risk. Investors strongly prefer to pass through these costs to distribution utilities (DUs), given the price volatility of fossil fuels (international commodity prices and exchange rates).

Capital recovery fee: There are very high, medium, and low requirement levels for hydropower, coal, and HFO/diesel, respectively. In six out of eight PPAs, the capital recovery is on a kWh basis. The exceptions are DPC 2012 and DPI 2017, where cost recovery is on a kW/month basis, the investor's ideal.

Off-grid subsidy agreement: ERC approved seven of the eight PPAs that Paleco submitted for approval, including the off-grid subsidy agreement. The exception is LPC's PPA, which ERC did not approve or reject. However, LPC did not pursue the PPA approval process further with ERC, hinting at other investment issues. The subsidy agreement between NPC and generators has historically paid for half the generation rate cost (TCGR).

Buying commitments: Investors can mitigate investment risk by securing a solid energy-buying commitment. Paleco did not commit to purchasing any amount of energy in all eight PPAs it signed. Paleco granted priority dispatch to PPGI 2009 and LPC 2016. For other PPAs, Paleco granted several lower dispatch preferences, leaving investors with a higher volume risk. In the case of LPC (hydropower), Paleco committed to buying all delivered energy but leaving volume risk caused by resource uncertainty and variability with investors.

Type of power: It is easier for fossil fuels to deliver baseload, mid-merit, or peaking power since they provide firm power, i.e., power available upon demand. RE is often variable and intermittent, contingent on resource availability. Every PPA specifies the type of power it needs to deliver, except LPC's PPA and DPC's emergency gensets (DPC 2012), per Table 6. DPC 2012 consists of DPC 2013's advanced capacity; hence, the type of power should be the same. Consequently, except for LPC 2016, all PPAs require some type of firm power that is difficult to achieve independently with most forms of renewable energy.

Table 6. Type of power.

PPA	PPGI 2009	PPGI 2010	DPI 2009	DPC 2012	DPC 2013	DPC 2017	DPI 2017	LPC 2016
Type of power	Peak, reserve	Base, peak	Base, interim, peak	N/a	All active power and reserves	Base, interim, peak	All active power and reserves	N/a

Source: Off-grid dataset (Supplementary Materials).

Guaranteed dependable capacity: This requirement gives fossil fuels an advantage since they are dispatchable, unlike solar, wind, and hydro run-of-river, which are intermittent and variable. Paleco started requiring a guaranteed dependable capacity (GDC) in 2009. The exception is LPC 2016's hydropower PPA. DPC 2013's GDC is included in the 25 MW DPC 2017 GDC.

Technology requirements: Starting in 2015, Paleco's competitive selection process (CSP) excludes coal technology due to social opposition and long delays in implementing DPC's coal project.

Time to commercial operations date (COD): A tight deadline favors oil plants (diesel and HFO) due to their short development and construction cycle relative to RE. Table 5 shows that time to COD requirements for fossil fuels, ranging from 2 to 13 months, are much shorter than hydropower at 30 months. A very tight COD of 2 months made an investment unviable for DPC 2012 (genset rentals instead) and only possible for DPI 2009 since the power plant is already operating and only requires rehabilitation. On the other hand, a COD of 30 months for hydropower is a very tight deadline, given the long access roads and heavy civil works involved.

Contract term: A total of 15 years is the most common contract term, representing four out of eight PPAs. Other terms are 9 months for DPC's emergency diesel Genset (making an investment unviable), 10 and 12 years for HFO, and 25 years for LPC's hydropower. Investors prefer long-term PPAs (at least 10 years), especially with capital-intensive technologies such as hydropower and coal.

Power plant location: Urban location requirements limit RE deployment since RE is site-specific. Most PPAs (PPGI 2009, DPI 2009, DPC 2012, DPC 2013 (initially), DPI 2017) require the power plant to be in Puerto Princesa City, Palawan's capital, responsible for most of Paleco's demand. In 2019, around three-quarters of the power capacity was in Puerto Princesa. These locations are existing power plant sites with land available and existing infrastructure, such as access roads and interconnection, which favored fossil fuel investors. Other locations are suburban and outside urban areas.

Grid interconnection: Investors favor projects near existing local grid interconnections to minimize costs and delays. Unlike fossil fuels, RE is site-specific and land-intensive; thus, RE investors cannot always locate projects within urban centers or near existing grid connections. Most PPAs require delivery at Paleco's existing distribution line, which minimizes investors' Capex, except PPGI 2010, DPC 2017, and LPC, for delivery outside Puerto Princesa. Power plants connected to the transmission grid involve payment of transmission fees and investment in interconnection assets. LPC needs to invest in three tie-in lines to NPC's 69 kV transmission lines with a combined length of 40.5 km and respective access roads.

5.2. Evaluation of Risks' Severity of Impact

The paper uses sensitivity analysis to measure the PPA risks' severity of impact. A higher impact of the risk on ROE denotes a higher severity of impact. The paper builds representative financial models for each key off-grid technology (HFO, diesel, small coal, and run-of-river hydropower) and then conducts a sensitivity analysis on the selected risk (e.g., variable O&M cost). Each financial model replicates the typical financial variables (e.g., capacity factor, power plant useful life) for each technology in Palawan during the analysis period. Although Paleco did not sign any solar PPA during the period, the paper adds it to the analysis, given its future potential. Tables A1 and A2 in the Appendix A show the financial models' base case scenario assumptions and the risks the PPA can mitigate with simulation scenarios analysis. The references section includes links to the financial models and detailed sensitivity analysis (Supplementary Materials).

Table 7 shows the ROE percentage change versus the base case. It assumes that changes in the PPA risk (e.g., 10% higher fixed O&M costs) decrease the ROE while the rate charged to consumers remains the same. An ROE decrease from 12.2% (base case) to 6.1% represents a decrease of 50% in the ROE. Table A3 in the Appendix A shows the ROE for the different sensitivity analysis scenarios. All ROEs that decrease by 15% or more are shaded gray, and the corresponding PPA risks are the most severe. The severity of the risks depends on the technology.

For HFO and diesel, the most severe risks are fuel costs, followed by Paleco's creditworthiness (default). Other severe risks are lower volume, construction delay, and changes in capital recovery fees. For coal, Paleco's creditworthiness is the most severe risk, followed by volume, construction delays, fuel cost, capital recovery fee changes, investment cost, and increased capital cost due to lower parties' creditworthiness. RE exhibits the most severe risks. Paleco's creditworthiness (default) is the most severe risk, followed by the inability to provide guaranteed dependable capacity and locate closer to load. Other severe risks are volume, capital recovery fee, investment cost, construction delay, and higher capital costs due to parties' creditworthiness.

Table 7. PPA risk severity of impact: sensitivity analysis (total ROE percentage (%) change versus base case).

PPA Risk	Simulation	HFO	Diesel	Coal	Solar	Hydro
Parties creditworthiness	+10% cost of capital (CoC)	0%	0%	−11%	−14%	−14%
Parties creditworthiness	+10% CoC + lower debt %	0%	0%	−27%	−23%	−23%
Parties creditworthiness	Paleco's default	−61%	−42%	−338%	−545%	−626%
Variable O&M cost	+10%	−6%	−12%	−6%	−1%	−1%
Fixed O&M cost	+10%	−5%	−12%	−13%	−7%	−4%
Fuel cost	+10%	−32%	−89%	−39%	0%	0%
Fuel cost	Average fuel cost	#NUM!	#NUM!	14%	0%	0%
Capital cost	−10%	−13%	−16%	−30%	−32%	−32%
Capital cost (invst.)	+10%	−12%	−14%	−27%	−29%	−29%
Volume	−10%	−18%	−29%	−43%	−39%	−36%
GDC	Fossil fuel and RE	0%	0%	0%	#NUM!	−122%
Deployment time	+1 year	−17%	−19%	−40%	−27%	−27%
Contract term	−10%	−4%	−7%	−10%	−10%	−10%
Plant location	Next to load	0%	0%	−13%	−66%	−107%
Grid interconnection	Next to load	0%	0%	10%	29%	19%

TABLE LEGEND: *ROE changes by 15% or more*

Note 1: The ROE percentage change = (simulation scenario ROE/base case scenario ROE) × 100 − 100. Note 2: "#NUM!" means that the change in ROE is highly negative, and Excel could not calculate an exact value. Source: Model and sensitivity analysis worksheet (Supplementary Materials).

5.3. Investment Decisions

Given the risks' likelihood of occurrence and severity of impact if they occur, investors took the following decisions described below and summarized in Table 8.

Table 8. Investor's decisions summary table.

PPA	PPGI 2009	PPGI 2010	DPI 2009	DPC 2012	DPC 2013	DPC 2017	DPI 2017	LPC 2016
Investment: yes or no	Yes	Yes	Yes	No (rental)	D: yes; C: no	Yes	Yes	No
Technology choice	Diesel/HFO	Diesel/HFO	HFO	Diesel	Diesel/coal [(1)]	HFO	HFO	Hydro [(1)]
New or old power plant and site	Old plant and site (rehab)	New site	Old plant and site (rehab)	Old site	New site	Old site	Old site	New site
New or old equipment	Old	Old	Old	Old	D: old; C: new [(1)]	Old	Old	New [(1)]
Investment (USD millions/MW)	0.34	0.41	0.50	n/a	D: 0.5 C: 3.5 [(2)]	1.10	1.01	4.93 [(2)]
Actual financing	Equity	Equity	Equity	n/a	Equity	Equity	Debt	n/a
Investment timeframe	5 yrs.	6 yrs.	mos.	mos.	1 yr./n/a	1 yr.	1 yr.	n/a

Source: Off-grid dataset (Supplementary Materials). Footnotes: [(1)] Planned investment but did not materialize; [(2)] Paper-derived cost. Note: "D" stands for diesel, and "C" stands for coal. HV: high voltage; LV: low voltage.

Invest or not invest: Six of eight PPAs led to investments. The exceptions are LPC's hydropower PPA and DPC 2012, the latter consisting of a diesel genset rental. DPC 2013's PPA led to investment first in diesel and then HFO but not in the primary technology, coal.

Technology choice: Of the planned investments, one was hydropower, one was coal, four were HFO, and two were diesel. Investors did not finance the hydropower and coal power plants. DPC replaced the coal power plant with a combination of diesel and HFO. Consequently, Paleco ended up with just diesel and HFO power plants, which require low upfront investments but are expensive to run.

New or existing power plant: The power plants of five PPAs are located on existing power plant sites using old equipment. The old locations are PPGI 2009 and DPI 2009, PPAs that just took over existing NPC power plants. DPI 2017 is co-located on DPI 2009's site. DPC 2012 emergency Genset is likely located in an existing facility to speed up installation, and DPC 2017 in Aborlan is likely on-site with already existing diesel DPC gensets. The exceptions (new sites) are LPC since hydropower is site-specific, DPC 2013, and PPGI 2010.

New or old equipment: All seven investments (including one rental) seem to consist of old equipment. Of the seven investments, two are rehabilitations of NPC's old power plants (PPGI 2009 and DPI 2009), two use old diesel Gensets (DPC 2012 and DPC 2013),

of which the latter is a rental, and three are relocations and rehabilitations of old power plants/equipment (PPGI 2010, DPC 2017, and DPI 2017). PPGI 2009 took over a lease–rehabilitate–operate–maintain (LROM) contract that Paleco had with NPC for an old NPC HFO power plant in Puerto Princesa. DPI 2009 PPA effectivity started when the supply contract between NPC and Paleco ended in 2009. However, the underlying asset for both contracts was the same NPC Puerto Princesa power plant that DPI had already been operating since 2004. PPGI 2010 PPA claims the investment consists of a greenfield power plant, but the equipment seems to have been rehabilitated given the low investment cost. For DPC 2017, the engines procured were old Wartsila engines that would have required significant rehabilitation, and no original equipment manufacturer warranty is available for fuel-efficiency guarantees per the last ERC application. DPI 2017 consisted of four Wartsila rehabilitated engines. DPC 2012 consisted of emergency rental diesel gensets. DPC 2013 seems to be a mix between rentals and new diesel gensets.

Investment per MW: Table 8 shows the investment cost per MW in USD millions. LPC's hydro exhibits the highest cost per MW, estimated at USD 4.9 million, followed by DPC's coal plant at USD 3.50 million per MW. In contrast, diesel and rehabilitations exhibit the lowest at USD 0.34 to 0.50 million per MW.

Investment financing: Table 9 shows the long-term financing of the investment as reported in the financial statements and the planned financing reported in the PPA application. Investors financed the investments mostly with equity. The exception is DPI 2017, financed primarily with debt, although DPI disclosed in the PPA application that, initially, it planned to finance the power plant with equity. DPC stated in the PPA application their intent to fund their DPC 2017 investment with long-term debt, but it was fully funded with equity instead. DPC 2017 and LPC 2016's planned financing, and DPI 2017's actual financing show investors' objective to primarily finance investment with long-term debt. However, banks were reluctant to extend long-term loans without proper risk mitigation measures.

Table 9. PPAs investment financing.

PPA	PPGI 2009	PPGI 2010	DPI 2009	DPC 2012	DPC 2013	DPC 2017	DPI 2017	LPC 2016
LT debt %	1	−9	0	n/a	−2	1	77	n/a
Equity %	99	109	100	n/a	102	99	23	n/a
Planned financing (per PPA)	Equity since PIRR = 13.25%	Equity since PIRR = 14.58%	100% equity at 14.6%	n/a but minimal investment	n/a	70% debt at 8%, 30% equity at 11.9%	100% equity at 12.23%	Mix of debt and equity

Source: SEC financial statements (change in balance sheets): LT (long-term) debt, equity; PPA ERC applications (planned financing). Source: Off-Grid Dataset worksheet (Supplementary Materials). Note 1: The analysis considers shareholders loans/payables as equity since the loans are not from a financial institution. Note 2: Negative LT (long-term) debt means debt reduction, i.e., equity-funded investment and LT debt repayment.

Investment timeframe: DPI 2009 and DPC 2012 just took a few months between the PPA signing and the start of commercial operations. In the first case, DPI took over an existing NPC power plant; in the second case, DPC rented diesel gensets.

For DPC 2013, DPC 2017, and DPI 2017, the time elapsed ranged from one year to one year and a half. PPGI's PPAs took four to six years to reach commercial operations, including three to four years to file the PPA application with the regulator. This delay might have been due to regulatory uncertainty but more likely, due to the lack of financial capacity of Power One Corporation. This entity initially signed the PPA with Paleco and only managed to secure financing from PPGI's majority investor several years later.

5.4. Energy Outcomes

The investor's decisions had a major impact on Palawan's energy affordability, security, and sustainability.

Energy affordability: Hydropower, the lowest cost technology, at USD 13.16 cents per kWh, did not receive funding. Instead, Paleco relied on expensive diesel and HFO power plants with approved generation rates ranging from USD 16.05 to 25.60 cents per kWh, as Table 10 shows. This rate is more than double the rate of the main grid of around USD 10 cents per kWh. While the SAGR to consumers in Palawan remained constant at USD 11.28 cents, all electricity consumers in the Philippines paid for the subsidy cost.

Table 10. True cost generation rate (TCGR)—USD cents/kWh.

PPA	PPGI 2009	PPGI 2010	DPI 2009	DPC 2012	DPC 2013	DPC 2017	DPI 2017	LPC 2016
Technology	Diesel/HFO	Diesel/HFO	HFO	Diesel	Diesel/coal	HFO	HFO	Hydro
Capital recovery rate (CRR)	2.12	2.70	2.86	2.16	3.30/7.34	4.23	3.94	13.16
O&M rate	3.22	2.20	3.88	n/a	1.94/3.80	2.10	3.14	0.00
Fuel rate	15.68	15.68	14.08	n/a	20.36/7.60	9.72	9.42	0.00
TCGR	21.02	20.56	20.82	n/a	25.6/18.76	16.05	16.50	13.16

Source: Off-grid dataset (Supplementary Materials). Originally in Php but converted at Php 50 to USD 1 (30 July 2021 exchange rate).

Energy security: During the analysis period, Palawan boomed economically but struggled to meet its supply and reliability power needs. Private investors took over and rehabilitated old NPC power plants (PPGI 2009 and DPI 2009) without constructing new, more reliable ones. Reliability was a critical issue, which is clear from PPA ERC applications, with statements such as "In the past few years, DPC failed to meet its guaranteed dependable capacity" [39]. During the analysis period, LPC did not deploy its hydropower plant, nor did DPC deploy its coal power plant, compounding supply problems. These issues contributed to the take-over of Paleco's management by NEA at the end of 2018.

Environmental sustainability: All PPA installations during the study period consisted of highly polluting fossil fuels, such as diesel and HFO, and they mainly used equipment with inherently lower fuel efficiency consumption than new equipment.

6. Discussion

Table 11 classifies the PPA risks into extreme, high, medium, and low, using the risk evaluation matrix described in Figure 3 that combines the likelihood of occurrence (Table 5) and severity of impact (Table 7). The resulting investor's decisions (Table 8) are at the bottom for ease of analysis. Investors did not finance PPAs with numerous extreme risks (high likelihood and severity). This is the case with LPC 2016 (hydro), DPC 2012 (diesel rental), and DPC 2013 (coal) with seven, four, and five extreme risks, respectively. All other PPAs led to investments but exhibited two common extreme risks: Paleco's low creditworthiness and lack of buying commitments. Consequently, investors structured their investment to minimize capital at risk by choosing low-capital intensive technologies (diesel and HFO), existing infrastructure (sites and power plants), and used equipment. In DPI 2017's case, Paleco mitigated the volume risk by structuring fixed costs (capital and fixed O&M) as fixed monthly fees instead of variable payments; thus, the investor secured bank financing. In all other cases, investors had to use their equity. These findings support the first hypothesis that PPA contract design significantly impacts off-grid investment decisions.

Table 11. Summary table: PPA risks and investor's decisions.

PPA	PPGI 2009	PPGI 2010	DPI 2009	DPC 2012	DPC 2013	DPC 2017	DPI 2017	LPC 2016
Technology	Diesel/HFO	Diesel/HFO	HFO	Diesel	Coal/Diesel	HFO	HFO	Hydro
Capacity—MW	7.2	10.0	16.0	5.0	27.0	9.9	30.3	17.8
Risks PPA Mitigates:								
Creditworthiness—investor								
Creditworthiness—Paleco								
Variable O&M cost								
Fixed O&M cost								
Fuel cost								
Capital cost					*Coal* *Diesel*			
Capital cost (invst.) [1]					*Coal* *Diesel*			
Off-grid subsidy								
Volume								
Priority dispatch								
Type of power								
GDC								
Time to COD [2] (months)								
Contract term (years)								
Plant location								
Grid interconnection								
Investor's Decisions:								
Investment: yes (Y) or no (N)	Yes	Yes	Yes	**No** (*Rental*)	**C: No** D: Yes	Yes	Yes	**No**
Technology choice	Diesel/HFO	Diesel/HFO	HFO	Diesel	Coal [3] Diesel	HFO	HFO	Hydro [3]
New or old power plant	Old plant, old site	New site	Old plant, old site	Old site	New site	Old site	Old site	New site
New or old equipment	**Old**	**Old**	**Old**	**Old**	C: new [3] **D: Old**	**Old**	**Old**	New [3]
Investment (USD millions/MW)	**0.34**	**0.41**	**0.50**	n/a	**C: 3.5** [4] D: 0.5	1.10	1.01	**4.93** [4]
Actual financing	**Equity**	**Equity**	**Equity**	n/a	**Equity**	**Equity**	**Debt**	n/a
Investment timeframe	5 yrs.	6 yrs.	mos.	mos.	1 yr.	1 yr.	1 yr.	n/a

Table Legend: *Extreme Risk* *High Risk* *Medium Risk* *Low Risk*

Source: Off-grid dataset (Supplementary Materials) and model and sensitivity analysis worksheet (Supplementary Materials). [1] *Upfront investment required as indicated in the PPA application to ERC and derived from the capital recovery rate.* [2] *Time to COD: from PPA signing (DPI 2009, DPC 2012, DPC 2013); from Regulator Approval (DPC 2017, DPI 2017, LPC 2016).* [3] *Planned investment but did not materialize.* [4] *Paper-derived cost. Note: "D" stands for diesel, and "C" stands for coal.*

The investor's risk mitigation decisions also resulted in biasing investments toward low-capital intensive fossil fuel technologies, affirming hypothesis 2, as explained in this paragraph. Given PPA's residual (extreme) risks, the investors minimized capital at risk by choosing diesel and HFO since these technologies are low-capital-intensive when compared with hydropower and coal, both of which did not materialize, exhibit low sunk costs since they are modular and mobile; hence, they can easily re-located in case of Paleco's default, unlike coal and renewable energy, and they can be operated with used equipment and installed near the load or on existing sites, unlike RE that is site-specific. Paleco's procurement requirements, such as tight installation periods, guaranteed dependable capacity (GDC), and specific power types (e.g., baseload or peak), also benefited diesel and HFO. Hydropower and coal take several years to construct, unlike diesel and HFO. RE's intermittency and variability make it difficult to provide firm power (GDC and power type). RE can provide firm power by combining it with batteries (expensive at the time of the study) or diesel and HFO, but this makes the projects more complex and costly, forcing RE developers to go beyond their core competency. Fossil fuel pass-throughs and the off-grid subsidy canceled out the main advantages of RE, low cost and price stability. These resulted in a non-internalization of fossil fuel's high cost and volatility by the primary PPA decision-makers, i.e., investors, Paleco, and Paleco's energy end-users. Instead, the universal off-grid subsidy passed fossil fuel's high cost and volatility to all Philippine on-grid consumers. Consequently, Paleco's transition to RE was greatly delayed.

According to the energy trilemma [59], there is a trade-off among energy affordability, environmental sustainability, and supply security, but Paleco ended up with high-cost, polluting, and unreliable energy. Diesel and HFO are the most expensive technologies due to their high fuel cost and used equipment's low efficiency. Paleco's energy cost was double the Philippines' grid. While fuel was the main cost component, O&M and capital costs were also high. O&M cost was high due to used equipment and consequent lack of original equipment manufacturer's warranties. Capital costs were also high, given that PPA residual risks did not provide the certainty necessary to obtain bank financing to substantially lower the capital cost. Consequently, most investors had to finance their projects primarily with equity, the most expensive capital, which also impacted the financial viability of capital-intensive projects like RE and coal. Diesel and HFO are peak power technologies, but Paleco was operating them as mid-merit or base load, which contributed to a lack of reliability and high cost, especially if the equipment was not new.

7. Conclusions

The paper identified and evaluated PPA risks according to the likelihood of occurrence and severity of impact and, as a result, classified them into low, medium, high, and extreme risks. These risks offer a clear explanation for the investment decisions, affirming the paper's hypotheses. In the traditional literature, a PPA is seen as just a revenue source or, at best, a project risk-mitigation tool. This paper goes a step further and contributes to the literature by showing that, if the PPA fails to mitigate critical risks, the investment itself becomes the risk mitigation tool, which is suboptimal and can result in an expensive, polluting, and unreliable power system, delaying energy transitions from fossil fuels to renewable energy. This is the case with Palawan's power system despite the available renewable energy options, hydropower and solar, being more affordable and cleaner than diesel and HFO, the only deployed technologies. Given the inherited limited ways to mitigate investor risk in off-grid areas, the paper highlights the critical importance of properly designing a PPA to enable and accelerate energy transitions. A key implication is the need for the government and distribution utilities to work together to mitigate RE PPA risks. The government needs to rationalize subsidies that advantage fossil fuels and strengthen distribution utilities' creditworthiness.

The paper provides a structured, novel, and efficient methodology to evaluate PPA risks, improving PPA design and the investment decision process. However, PPAs are not a fit-all solution since they will still not be viable when energy consumption is subscale, making transaction costs too high, when energy customers lack fundamental creditworthiness, and when energy consumption is unpredictable. An area of future research is the impact of non-PPA investment drivers on off-grid investment decisions, such as political and social drivers, which are likely to have made the investors even more risk-averse.

8. Policy Recommendations

Paleco needs to reduce investors' uncertainty and secure affordable, reliable, and clean energy by: committing to buying power or energy; covering reasonable fixed costs from generators; contracting hybrid solutions (renewable energy, batteries, or fossil fuels) or standalone renewable energy, which would lower the total generation cost; complementing VRE with dispatchable generation sources at the central level; correcting its procurement process by forward contracting and scheduling PPA bids and respective power plant deployment years in advance and conducting PPA bids under an open and competitive selection process; requiring original equipment manufacturer's warranties; and being environmental proactive by actively seeking affordable renewable energy solutions. Reducing investor uncertainty will attract private capital, especially debt financing, lowering the cost of capital and equity requirements.

Policymakers need to level the playing field between fossil fuels and renewable energy and remove market distortions by: narrowing the scope of off-grid subsidies in urban or tourist areas (privileged areas) and focusing on rural areas (underprivileged areas);

considering instead non-price distorting assistance directly to poor end-users; reviewing the least-cost methodology for PPA evaluation, given the price volatility of fossil fuels; focusing on total generation cost instead of on subsidized rates, by benchmark cost against on-grid areas; and allowing new large industrial and commercial loads to contract directly with investors instead of going through Paleco. The government should consider increasing Paleco's creditworthiness by providing a revenue payment or bank loan guarantee to affordable RE projects to facilitate its implementation instead of spending subsidies on easy-to-implement but high-cost, polluting, and unreliable fossil fuel projects.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/en16186645/s1: "Off-grid Dataset" and "Model and Sensitivity Analysis" worksheets.

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Abbreviations

AS	Ancillary services
C	Coal
CF	Corporate finance
COC	Cost of capital
COD	Commercial operations date
COE	Cost of equity
CRF	Capital recovery fee
CRR	Capital recovery rate
CSP	Competitive selection process
D	Diesel
DOE	Department of Energy
DPC	DMCI Power Corporation
DPI	Delta P, Inc
DU	Distribution utility
EC	Electric cooperative
ECC	Environmental compliance certificate
ERC	Energy regulatory commission
FOM	Fixed operations and maintenance
GDC	Guaranteed dependable capacity
GHG	Greenhouse gas
GW	Gigawatt (a unit of power)
HFO	Heavy fuel oil
IRR	Internal rate of return
HV	High voltage
KM	Kilometer
kW	Kilowatt (a unit of power)
kWh	Kilowatt-hour (a unit of energy)

LGU	Local government unit
LPC	Langogan Power Corp.
LT	Long-term
LV	Low voltage
M	Million
MO	Month
MW	Megawatt (1000 kilowatt), a unit of power
MWh	Megawatt-hour (1000 kilowatt-hours), a unit of energy
NEA	National Electrification Administration
NGO	Non-governmental organizations
NPC	National Power Corporation
OEM	Original equipment manufacturer
O&M	Operations and maintenance
Paleco	Palawan Electric Cooperative
PEP	Philippines Energy Plan
PF	Project finance
PHP	Philippines peso
PIRR	Project internal rate of return
PPA	Power purchase agreement; other names for PPA are PSA (power supply agreement) or ESA (electricity supply agreement) or offtake agreement.
PPGI	Palawan Power Generation Inc.
RE	Renewable energy
ROE	Return on equity
RPS	Renewable portfolio standard
SA	Subsidy agreement
SAGR	Subsidized approved generation rate
SO	System operator
ST	Short-term
TCGR	True cost generation rate
USD	United States dollars
VAT	Value-added tax
VOM	Variable operations and maintenance
VRE	Variable renewable energy
WACC	Weighted average cost of capital

Appendix A

Table A1. Financial model base case scenario assumptions.

Financial Variable	Units	HFO	Diesel	Coal	Solar	Hydro
Energy:						
Capacity	MW	20	10	25	25	20
Capacity factor	%	60%	40%	70%	20%	50%
Guaranteed dependable capacity	Yes/No	Yes	Yes	Yes	No	No
Reaches commercial operations	Yes/No	Yes	Yes	Yes	Yes	Yes
Investment:						
Investment	USD M/MW	1.078	0.500	2.844	1.359	4.932
Power plant useful life	Years	15	10	20	25	25
Construction delay	Years	0	0	0	0	0
Terminal value/investment	%	5%	5%	5%	5%	5%
Working capital (weeks of fuel)	Weeks	2	2	2	0	0
Power plant location	Area Type	City	City	Suburb	Rural	Rural
Land area	Hectares/MW	0.09	0.09	0.37	1.00	5.00
Percentage of land acquired	%	0%	0%	100%	100%	5%
Land price in Palawan	USD/Sqm	50.2	50.2	13.1	13.1	1.8
Switchyard and transformer	USD K/MW	75.8	75.8	75.8	75.8	75.8
Transmission line cost	USD K/Km	69.8	23.2	69.8	69.8	69.8
Transmission line length	Km	0	0	5	15	40.5
Access road	USD k/Km	20	20	20	20	50
Access road length	Km	0	0	5	9	24.3
Fuel Cost:						
LFO consumption rate	Liters/kWh	0.01	0.28	0.00	0.00	0.00
HFO consumption rate	Liters/kWh	0.24	0.00	0.00	0.00	0.00
Coal consumption rate	Kilos/kWh	0.00	0.00	0.84	0.00	0.00
Light fuel oil price (ex-Vat)	USD/L	0.55	0.55	0.0	0.0	0.0
Heavy fuel oil price (ex-Vat)	USD/L	0.37	0.37	0.0	0.0	0.0
Coal price (ex-Vat)	USD/kilo	0.0	0.0	0.09	0.0	0.0
Operations and Maintenance Cost:						
O&M fixed rate	USD Cent/kWh	1.48	2.40	2.60	1.88	1.52
O&M fixed rate (equivalent)	USD/mo./KW	6.52	7.03	13.25	2.74	5.56
O&M variable rate	USD Cent/kWh	1.92	2.38	1.22	0.20	0.28
Cost of Capital:						
Interest rate (cost of debt)	%	8.0%	8.0%	8.0%	8.0%	8.0%
Debt/investment	%	0%	0%	70%	70%	70%
Income tax rate	%	30%	30%	30%	10%	10%
Cost of equity	%	12.2%	12.2%	12.2%	12.2%	12.2%
Equity/investment	%	100%	100%	30%	30%	30%

Note: Regulator approved rates and costs are the same in the base case scenarios. Source: Model and sensitivity analysis worksheet (Supplementary Materials). USD values originally in Php but converted at Php 50 to USD 1 (30 July 2021 exchange rate).

Table A2. Sensitivity analysis simulation scenarios.

Risk PPA Mitigates	Simulation	Explanation
Parties creditworthiness	+10% cost of capital (CoC)	Cost of capital, that is cost of debt and equity, increases by one-tenth (10%)
Parties creditworthiness	+10% CoC + lower debt %	Cost of capital increases by one-tenth, and debt/capital decreases by 20% (e.g., 70% to 50%)
Parties creditworthiness	Paleco's default	Paleco defaults 5 years after COD; residual value a fraction of initial investment.
Variable O&M cost	+10%	Variable O&M cost increases by 10%
Fixed O&M cost	+10%	Fixed O&M cost increases by 10%
Fuel cost	+10%	PPA benchmark fuel price (Php/L or Php/kilo increases) by 10%
Fuel cost	Average fuel cost	Historical average fuel price for the period instead of PPA benchmark price
Capital cost	+10%	Capital costs increase by 10%
Capital cost (investment)	+10%	Investment cost increases by 10%
Volume	−10%	Energy Delivered is lower by 10%
GDC	Fossil fuel and RE	RE forced to provide dependable capacity by hybridizing with firm technologies
Deployment time	+1 year	Project construction extended by 1 year
Contract term	−10%	Contract duration shortened by 10%
Plant location	Next to load	RE and coal located in urban area like diesel/HFO
Grid interconnection	Next to load	RE and coal located next to grid like diesel/HFO

Source: Model and sensitivity analysis worksheet (Supplementary Materials) contains detailed scenarios calculations.

Table A3. Actual return on equity (ROE)—%.

Investment Driver	Simulation	HFO	Diesel	Coal	Solar	Hydro
Base case	Base case	12.2%	12.2%	12.2%	12.2%	12.2%
Parties creditworthiness	+10% cost of capital (CoC)	12.2%	12.2%	10.9%	10.5%	10.5%
Parties creditworthiness	+10% CoC + lower debt %	12.2%	12.2%	9.0%	9.4%	9.5%
Parties creditworthiness	Paleco's default (5th year)	4.7%	7.1%	−29%	−54%	−64%
Variable O&M cost	+10%	11.5%	10.8%	11.5%	12.1%	12.1%
Fixed O&M cost	+10%	11.6%	10.7%	10.6%	11.4%	11.7%
Fuel cost	+10%	8.4%	1.3%	7.5%	12.2%	12.2%
Fuel cost	Average fuel cost	#NUM!	#NUM!	13.9%	12.2%	12.2%
Capital cost	+10%	10.6%	10.2%	8.6%	8.3%	8.3%
Capital cost (invst.)	+10%	10.8%	10.4%	9.0%	8.7%	8.7%
Volume	−10%	10.0%	8.7%	7.0%	7.5%	7.8%
GDC	Fossil fuel and RE	12.2%	12.2%	12.2%	#NUM!	−2.7%
Deployment time	+1 year	10.2%	9.9%	7.4%	8.9%	8.9%
Contract term	−10%	11.8%	11.3%	11.0%	11.1%	11.1%
Plant location	Next to load	12.2%	12.2%	10.6%	4.2%	−0.9%
Grid interconnection	Next to load	12.2%	12.2%	13.4%	15.7%	14.5%

Note 1: "#NUM!" means that the change in ROE was highly negative, and Excel was not able to calculate an exact value. Source: Model and sensitivity analysis worksheet (Supplementary Materials).

Appendix B

Total cost generation rate calculation (TCGR)

The TCGR calculation method that ERC uses and refers to as the levelized cost of energy (LCOE) method is the following:

- Energy rate (Php/kWh) = TCGR (Php/kWh) = fuel rate (Php/kWh) + variable O&M rate (Php/kWh) + fixed O&M rate (Php/kWh) + capital recovery rate (Php/kWh).

  ERC defines TCGR as the rate to allow "recovery of just and reasonable costs and a reasonable return on investment" [60].

- Fuel rate (Php/kWh) = fuel cost per liter (Php/L) × fuel consumption rate (L/kWh);
  The fuel rate is subject to a maximum fuel consumption cap. The three types of fossil fuel for Paleco are heavy fuel oil (HFO), diesel, and coal. If the fuel cost is pass-through and stays within the fuel consumption cap, then the fuel rate equals the fuel cost per kWh.

- Variable operations and maintenance rate (Php/kWh): these are O&M cost directly associated with energy generation (kWh), such as materials and supplies, water, and maintenance tied to hours of operations.

- Fixed operations and maintenance rate (Php/kWh) = annual fixed O&M costs (Php)/annual energy delivered (kWh);
  These are O&M expenses incurred regardless of whether the power plant is operating or not, such as labor, general business expenses, regular maintenance, and insurance.

$$\text{Fixed O\&M rate } (\text{Php/kWh}) = \frac{\text{annual fixed O\&M costs}}{\text{annual energy delivered } (\text{KWh})}$$

- Capital recovery rate (Php/kWh): annual capital recovery (Php)/annual energy delivered (kWh)
  Annual capital recovery (Php) = investment annualized value
  (for simplicity purposes, capital = investment)

  a. Investment annualized value = investment × annuity payment factor
     Investment (excluding VAT) = cost of civil works + electromechanics + project development + installation + construction insurance + interests during construction + others
     Annuity payment factor = $\frac{r}{1-(1+r)^{-n}}$, where n = PPA term (years) and r = cost of capital pre-tax.
     It represents the value of an annuity, given a cost of capital (pre-tax) of r and n number of annual payments, equivalent to 1 peso today. For example, given a cost of capital (pre-tax) of 8% and 10 annual payments, the annuity payment factor is 0.149, i.e., the present value of 0.149 pesos paid every year for 10 years equals the value of 1 peso today.

  b. R = cost of capital pre-tax = weighted average cost of capital (WACC) pre-tax

$$\text{WACC after tax } (\%) = \frac{\text{debt}}{\text{capital}} \times \text{cost of debt } \times \ (1 - \text{tax rate}) + \frac{\text{equity}}{\text{capital}} \ \times \ \text{costofequity}$$

$$\text{WACC pre-tax } (\%) = \text{WACC after tax } (\%)/(1 - \text{tax rate})$$

$$\text{WACC pre-tax } (\%) = \frac{\text{debt}}{\text{capital}} \ \times \ \text{cost of debt} + \frac{\text{equity}}{\text{capital}} \ \times \ \text{costofequity}/(1 - \text{tax rate})$$

Capital = investment;
The WACC is pre-tax and not after tax since it is used to calculate the capital recovery rate (CRR) that will still be subject to income tax;
Tax rate (%) = corporate income tax rate;
Cost of debt = interest rate, to simplify;
Cost of equity = 12.23% (ERC COE benchmark, source: 2016-082 RC). This is the cost of equity accepted by the regulator (ERC) during that the analysis period;
The capital structure, a mix of equity and debt financing, depends on the project, but banks typically provide 70% of the investment in debt in low-risk projects.

- Energy delivered (kWh) = project capacity (MW) × capacity factor (%) × 24 h × 365 days

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