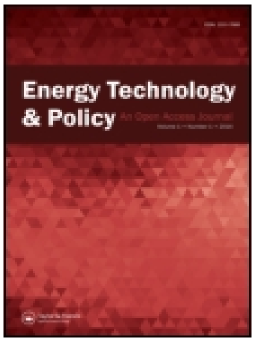

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Structuring Procurement to Improve Sustainability Outcomes of Power Plant Projects

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Abstract: Electricity consumption throughout Asia and the Pacific is projected to more than double from 2010 to 2035, reaching 16,169 terawatt-hours in 2035. While environmental factors are a pressing issue internationally, governments from developing countries in Asia also have a priority to deliver adequate power supplies to sustain their desired level of economic growth. The purpose of this article is to compare the implications of delivering power plant projects via either public private partnerships (PPPs) or traditional public procurement. A mixed method approach was used to evaluate four Indonesian power plant case studies. The article compares project performance based on project finance availability, construction and commissioning timelines, and operational reliability. It also investigates carbon emission factors from different power plant combustion technologies in relation to project financial structuring. The results show that (1) power plant projects that are procured through PPPs appear to be delivered in a more timely manner, and they have substantially better performance during the first years of operation than those of traditional public procurement; and (2) availability of project finance is influenced by a careful consideration of environmental and sustainability factors such as the selection of fuel type and the combustion technology.

Keywords: Procurement strategies, project finance, power plant technologies, project outcomes

1. Introduction

Developing countries in Asia require substantial investment in the energy sector to sustain their rapid economic growth, especially in emerging economies such as China, India, and Indonesia. For instance, it is estimated that Indonesian power plants will require US$97 billion of investment between 2015 and 2024 to meet economic growth projections.[1] The Indonesian public sector budget is simply not adequate to finance all the required infrastructure.[2,3,4]

Many Asian governments have undertaken regulatory reforms, aimed to improve productivity and attract private-sector investment for such infrastructure developments.[5] These reforms provide greater opportunities for private participation in energy infrastructure projects and in the commercialization of natural energy resources.[6] However, this also raises a concern as to whether private-sector investment in the energy sector benefits a nation's energy supply security.[7] Countries dependent on importing energy have an additional concern from the adverse impact of energy price fluctuations in international markets. For example, Turkey (an energy-import-dependent country) had a foreign trade deficit of approximately US$44 billion in 2011, due largely to importation of coal and natural gas for electricity generation.[8]

A secure power supply needs significant capital investment to develop adequate capacity and to mitigate against exposure to the volatility in the price for fuel.[9] Some countries have adopted the single buyer electricity market model where governments invite private investment in electricity generation as independent power producers.[10] In this market model, the contractual relationships between the public and private sector is governed through a power purchase agreement that typically assigns the private sector to arrange finance, design, construction, and operation of a power plant facility in return for performance-based payments from the public-sector contracting party. This structure of contractual relationships is consistent with the general principles of public–private partnerships (PPPs) procurement. Accordingly, governments that adopt the single buyer electricity model have to strategically select between PPPs and traditional public procurement to develop a power plant project.

In this article, traditional public procurement is defined to cover the situation where a government raises project finance (typically via a blend of government budget and international

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loans) and undertakes the engineering and operation of the facility through a state electric company. The selection process needs to consider whether the chosen procurement method produces better project outcomes to create a sustainable energy system.[11]

Fossil fuel–based power plants are subjected to international scrutiny as to their global carbon emissions.[12] The Asian Development Bank projected that coal consumption in Asia and the Pacific economies is forecasted to increase by more than 50% between 2010 and 2035 because electricity demand in this period is projected to double, reaching 16,169 terawatt-hours in 2035.[13] Environmental sustainability issues in power plant projects have become a major concern for international finance institutions.

The structure of project finance in energy projects in emerging economies contains a mixture of finance from international development banks, export credit agencies, and commercial finance institutions. International development agencies and many international commercial finance institutions have now incorporated social and environmental sustainability into their lending due diligence processes.[14,15,16] These requirements have increased support for renewable energy projects and more efficient thermal-based power technologies. It is worth noting that pre-committed offtake agreements, sometimes called feed-in tariff policies, that aim to promote the deployment of renewable-based power plants may increase government budget exposure, although such policies create greater certainty of financial returns for the private sector.[17] Accordingly, consideration of fuel and technology selection can shape the structure of finance in a power project.

It is evident that the link between project finance structuring, performance targets, and environmental sustainability for power plant projects still needs to be quantified. Globally, project developers from the United States and European countries gained extensive experience with PPP power projects in the 1990s.[4] Regional emerging economies such as China and India have expanded their involvement in international infrastructure projects through a focus on promoting outlets for equipment supplies, project development services, and finance with support from their export credit agencies.[18,19] Governments from emerging economies can benefit from enhanced market competition between project developers for power plant projects. The choice of procurement strategy between PPPs and traditional public procurement can assist these governments to achieve the expected outcomes from power plant projects.

Albeit power projects face increasing pressure to achieve environmental sustainability, there is limited research that compares the implications of procurement strategies, fuel types, and combustion technologies toward project outcomes. Therefore, the aim of this article is to compare the outcomes achieved through the use of either a PPP mechanism or traditional public procurement for delivery of power plant projects in emerging economies. The article compares project outcomes of time and operational quality based on power projects delivered via either a PPP or traditional procurement in Indonesia. Appropriate outcomes from a power project are based on the assessment of project financial viability, construction performance, power supply availability, and environmental performance during project operation.

2. Methodology

A mixed methods approach was used to investigate four Indonesian power project case studies. Case study investigation is an appropriate framework to investigate a complex phenomenon that is specific and where there is little information known about the subject of investigation.[20,21] Specific measures of relative performance were used to compare project outcomes. This research then undertook within-case analyses to explain factors that led to different project outcomes. The within-case analysis can reveal the key explanatory variables that link to an outcome.[22]

This article compares the performance of the case study projects based on the two key project stages: the period between contract award and project commercial operation date (stage 1) and between commercial operation date and the first two years of project operation (stage 2), as presented in Figure 1. The commercial operation date (COD) is a substantial milestone that represents the completion of project construction and commissioning and indicates the commencement of the project operation phase.

Stage 1 of the analysis concentrates on time performance during project construction and commissioning. In Indonesia, on-time completion of the project construction and commissioning is essential if energy supply deficits are to be overcome.[23] The project financing process has been analyzed to reveal the typical structure adopted by project financiers and the commercial terms of their associated loan agreement. Stage 2 investigates project operating performance during the first two years of operation. The first operating years are considered the most critical because there may be technical defects that have not previously been identified during project commissioning and thus reduce the power plant operating performance.[24]

2.1 Project Performance Metrics

Time has been adopted as the metric to assess the performance during construction and commissioning. The project time performance was measured at two different project milestones between the time of government contract approval and the time of completion of project construction and commissioning. The project operation performance measures the power plant availability factor and carbon emission factor. The detailed performance metrics are discussed follows.

2.1.1 Project Time Performance

Analysis of the period between contract award and the completion of commissioning has been used to test any performance differences between PPPs and traditional procurement projects.[25] For traditional procurement, the time of contract signoff between the Indonesian government and the main contractor of the engineering procurement and construction (EPC) contract was selected as the time of project contract award. The PPP procurement used the time when the public and private parties signed off the power purchase agreement (PPA) as the time of project contract award. The completion of project construction and commissioning is a major milestone that indicates the commencement of commercial operation of a new power plant.

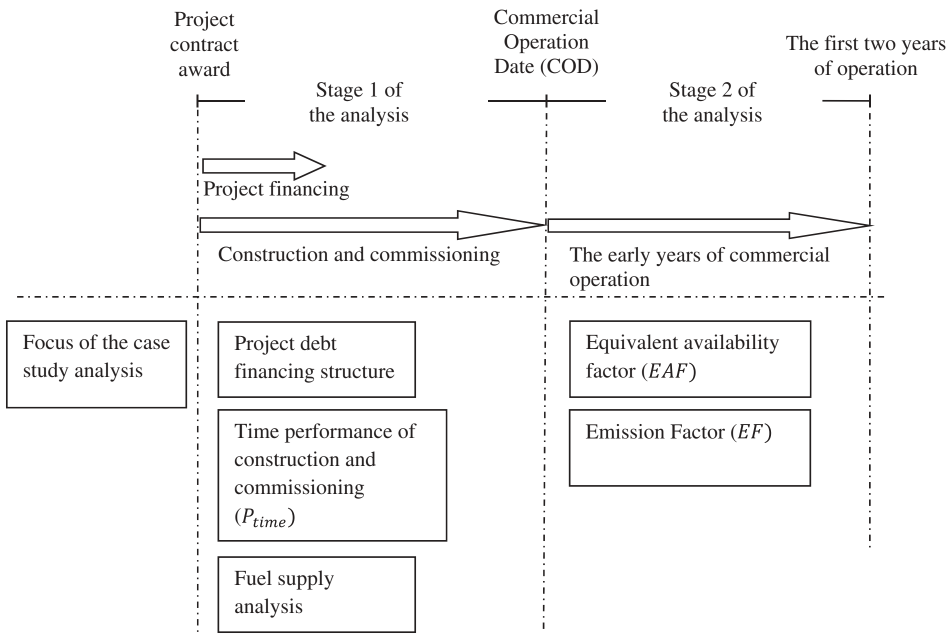

Fig. 1. Project stages that are investigated in the case study comparison.

The metric for measuring project time performance in PPPs and traditional power projects is expressed in equation (1).

$$P_{time} = \frac{T_{AC} - T_{CS}}{T_{CC} - T_{CS}} \quad (1)$$

Definitions:

P_{time}: Project time performance
T_{AC}: Actual finish date of project construction and commissioning
T_{CC}: Contractual finish date of project construction and commissioning
T_{CS}: Contractual start date of project construction and commissioning

2.1.2 *Project Quality Performance*

Assessment of project quality performance has been based on the availability of a power plant to operate according to its design capacity and carbon emission level. The equivalent availability factor (EAF) is used to measure project operation reliability, while an emission factor (EF) is adopted to investigate carbon emissions per megawatt hour (MWh) of electricity generated by each power plant unit. Early years of operational life of a power plant are essential to measure power plant performance, which is influenced by the commissioning process, potential random failures, and operating procedures.[26] The EAF index is derived from the international standard of IEEE number 762-2006, which measures the percentage of maximum electric generation available over a period of time.[27] The EAF index is considered to be one of the most important performance indices of power plant operating performance.[28] This measurement method has been recognized internationally and used by many international power utilities and organizations, such as the North American Electric Reliability Council (NERC).[29] The EAF index is measured in equation (2).

$$EAF = \frac{AG}{MG} \times 100\% \quad (2)$$

where

EAF: Equivalent availability factor on power plant *(i)* and unit number *(m)* thathas been procured using procurement method *(proc)*
AG: Available electricity generation from a power plant unit
MG: Maximum rated electricity generation from a power plant unit

This study also investigates the carbon emission levels in the power plant operation that is measured in the carbon emission factor (EF). The EF equation is adapted from United Nations Framework Convention on Climate Change (UNFCCC) emission factor formulas that are used for calculating electric power grid emissions, and it follows equation (3).[30]

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} x NCV_{i,y} x EF_{CO_2,i,y}}{EG_{m,y}} \quad (3)$$

where

$EF_{EL,m,y}$: CO_2 emission factor of a power plant unit *m* in year *y* (tCO_2/MWh)
$FC_{i,m,y}$: Amount of fossil fuel type *i* consumed by a power plant unit *m* in year *y* (mass or volume unit)
$NCV_{i,y}$: Net calorific value of fossil fuel type *i* in year *y* (GJ/mass)
$EF_{CO_2,i,y}$: CO_2 emission factor of fossil fuel type *i* in year *y* (tCO_2/GJ)
$EG_{m,y}$: Net quantity of electricity generated to the grid by power unit *m* in year *y* (MWh)
m: case studies of power plant units connected in year *y*

i: fossil fuel types combusted in power plant unit m in year y
y: year of the calculation (the first and second year operation)

It is worth noting that the case study projects utilize different fuel combustion technologies. Therefore, the EF results are not intended to be a direct comparison between PPPs and traditional public procurement as these projects typically utilize different power plant combustion technologies. It has been highlighted in the literature review that project finance markets are now moving toward more environmentally sustainable projects, and thus power projects that require financial support from the broader international finance communities need to adhere to environmental requirements. Therefore, it is important to evaluate the different emission factors from power plant technologies in relation to their respective project financial structuring.

2.2 *Case Study of Indonesian Power Projects*

One of the important processes in the case study analysis was the selection of the case studies.[20] Four representative Indonesian power plant projects were selected for this study, namely the Wayang Windu geothermal fired power plant (GTPP), the Cirebon coal-fired power plant (CFPP), the Cilegon combined cycle gas fired turbine (CCGT), and the Paiton-9 CFPP. The first of the two projects was procured through PPPs, while the other two projects were delivered via traditional public procurement. The key project information of the four power plant projects are summarized in Table 1.

The data source used to conduct the analysis was gathered from historical data on the power plant reliability operation from the Java-Bali Dispatch Centre; data on the calculation of power plant carbon emissions from the Ministry of Energy and Mineral Resources of Indonesia; public disclosure information regarding project capital costs and construction performance on traditional power projects; and official press releases from the project companies participating in the case study projects. Figure 2 illustrates indicative locations of the Indonesian case study projects.

3. Comparative Project Performance Analyses

The comparative performance analysis for the case study projects is divided into three sections. The first section investigates the financial structure of the case studies and then compares project time performance for both construction and commissioning. It also analyzes the respective power plant operating availability and carbon emissions.

Table 1. Case study data of Indonesian power plant projects.

	Public private partnerships (PPPs)		Traditional public procurement	
Key project information	Wayang Windu GTPP[31,32]	Cirebon Electric CFPP[33,34,35,36]	Cilegon CCGT[37,38,39]	Paiton-9 CFPP[40,41]
Fuel type	Geothermal	Coal	Natural gas	Coal
Combustion technology	Dry steam saturated geothermal technology	Supercritical pulverized technology	Combine-cycle gas turbine	Subcritical pulverized technology
Power capacity (MW)	117	660	740	660
Estimated project cost	US$300 m	US$850 m	US$345 m	US$ 460 m
Contractual date (T_{CS})	21 Nov 2006	20 Aug 2007	10 Feb 2004	12 Mar 2007
Date of financial close	13 June 2007	8 March 2010	5 November 2004	30-Jan-08 (USD) 18-Apr-08 (IDR)
Duration to reach financing closure	6.7 months	30.6 months	8.8 months	10.7 months (USD) 13.2 months (IDR)
Commercial operation date (T_{AC})	2 March 2009	27 July 2012	11 May 2006	9 June 2012
Contractual finish time (T_{AC})	13 March 2009	31 August 2011	31 October 2005	12 March 2010
Project sponsors/ Engineering Procurement and Construction (EPC) contractor	Star Energy	Marubeni (32.5%) KOMIPO (27.5%) Samtan (20%) Indika Energy (20%)	Mitsubishi Heavy Industries and Truba Jurong Engineering (EPC contractors)	Harbin Power Engineering and Mitra Selaras Hutama Energi (EPC contractors)
Fuel supply arrangement	a Joint-venture for geothermal resources development	Two energy companies, the Samtan and Indika Energy, participated in the project ownership structure	Natural gas supply contracts with a state gas distribution company and a natural gas producer	Annual coal supply contracts with domestic coal suppliers

Notes: GTPP: geothermal power plant; CFPP: coal-fired power plant; CCGT: cmbined cycle gas turbine power plant.

Fig. 2. Indicative location of the four case study projects on the Indonesian island of Java.

3.1 Financial Structure

Investigation of project financing structures is an important step in understanding the interests and commercial strategies of debt providers. It includes an analysis of project debt structures in both PPPs and traditionally procured projects.

There is a significant variation in project financing duration between the four case study projects examined (Table 1). The financing process in a PPP is typically more complex than traditional procurement. The commercial terms of the international creditors in the PPP projects requested government guarantees that contributed to a longer loan agreement process (e.g., approximately 30 months in the Cirebon Electric PPP project). The Wayang Windu GTPP obtained project financing in less than 7 months. A standard Indonesian PPP contract stipulates a period of 12 months for the private sector to reach financing closure from the date of contractual agreement. In traditional procurement, the public sector should complete the needed finance before it selects project developers.

The case study of the Cirebon Electric CFPP project (a PPP) received debt facilities totaling US$595 million from two international export credit agencies, namely the Japanese Eximbank (JBIC) and the Korean Eximbank, and international commercial banks. They included the Bank of Tokyo-Mitsubishi, Mizuho Corporate Bank, and the ING Bank N.V.[33,34] The two export credit agencies also provided political risk guarantees on loan portions provided by the commercial banks.

The Wayang Windu project received credit facilities of US$300 million from the loan syndication arranged by the Standard Chartered Bank of Singapore.[31] The financial institutions that participated in the loan syndication included the General Electric Energy Financial Services and two Indonesian state-owned banks, namely, the Bank Nasional Indonesia and the Bank Jawa Barat (Jabar).[42,43] This project sets a benchmark for Indonesian PPPs in that it did not require government guarantees to secure project loans because it has stable revenues from the existing power plant operation and the international carbon credit transaction.

Interestingly, project financing delays also occurred in traditional power projects. The Indonesian government required around 9 months for the Cilegon CCGT, and a year was taken to finalize bilateral loan agreements in the Paiton-9 CFPP from its international trading partners. In the Cilegon CCGT project, the Japan Bank for International Cooperation (JBIC) provided a loan facility amounting in total to ¥30.4 billion.[38] This loan was co-financed with international commercial banks, including the Bank of Tokyo-Mitsubishi, the Hong Kong and Shanghai Banking Corporation Limited, and Standard Chartered Bank.[38] The Paiton-9 CFPP received loan facilities from the Export Import Bank of China and PT Bank Mega, an Indonesian private bank, for US$331 million and IDR 601 billion, respectively.[40]

It can be seen that the geothermal power project and fossil-fuel-based power plants that utilize enhanced combustion technologies attract a broader range of project financiers. Loan syndications of these projects consisted of a mixture of international finance institutions. These institutions publicly supported more environmentally sustainable energy projects. Some were signatories to the equator principles, an international framework for socio-environmentally responsible lending practices.[44] It appears that the Cirebon Electric project that utilizes supercritical pulverized boiler technology was accepted by broader international finance communities, while the Paiton-9 project that adopted conventional subcritical pulverized boiler technology attracted only a limited pool of potential lenders.

This study shows that the international pressure on environmental sustainability has influenced the availability of project finance from international markets. However, Indonesian banks have maintained their flexibility in their lending policies. Project financing has a critical role in the development of a power plant project, and it may take a considerable time to finalize loan agreements. The international financial institutions often require project loan guarantees if long-term project revenues are not financially sustainable. Accordingly, the anticipated duration of the project financing process may affect the project completion schedule.

3.2 Time Performance of Construction and Commissioning

The results of the time performance of the case studies are presented in Figure 3 and show that the time performance ratio for three of the case study projects is above unity, while the

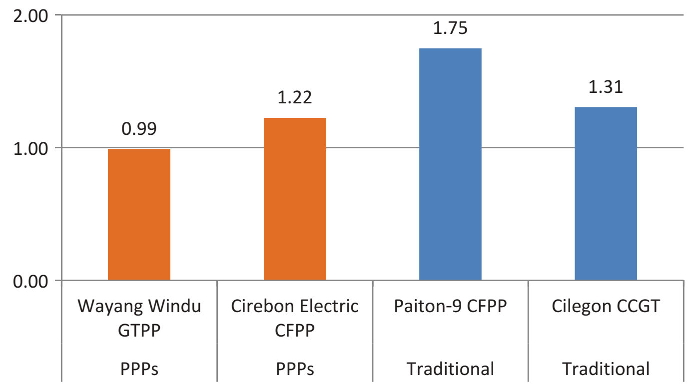

Fig. 3. Project time performance ratio for construction and commissioning.

Wayang Windu GTPP has a time ratio of just less than one. The Wayang Windu GTPP was the only project that was completed ahead of the original contractual schedule. In contrast, the other three projects had experienced completion delays. The project sponsors of the Wayang Windu GTPP contracted the Sumitomo Corporation as the main Engineering Procurement and Construction (EPC) contractor and Fuji Electric as the equipment manufacturer. These companies had developed the first unit of the Wayang Windu GTPP, which had a track record of high operational reliability.[45] The other PPP project, the Cirebon Electric CFPP, experienced the shortest ratio of completion delay of 22% over the original contractual schedule.

The private sponsors of these two projects utilized their internal cash flow to finance construction activities until debt finance was obtained from project financiers. This financing strategy specifically assisted the Cirebon Electric project to reduce the impact of delays from the debt financing process and avoided construction cost overruns.

The Cilegon CCGT project had a completion time overrun of 31% over the original contractual schedule, while the Paiton-9 CFPP was 75% over. These two projects were traditionally procured. The sources of delays were identified from fuel supply shortages, prolonged debt financing, and a power equipment breakdown. The Cilegon project was constructed in conjunction with a mega project valued at US$1.36 billion of the South Sumatera-West Java transmission gas pipeline.[37] The inadequacy of the natural gas supply from this pipeline project had prevented the EPC contractor of the Cilegon CCGT to complete the commissioning on schedule. The Paiton-9 project required around one year to finalize foreign and local loan agreements. This also delayed client progress payments to the EPC contractor which adversely affected their performance due to a lack of cash flow. The project was also delayed by 6 months because of a power transformer failure that required replacement.[41]

Based on these four case study projects, it appears that PPPs are completed in a more timely manner than the traditional procurement projects. The case study projects also indicate that construction performance can be managed by combined financial and technical decisions. Project sponsors of PPPs were incentivized to utilize their capital resources to finance construction albeit that debt facilities were not completely finalized. The availability of fuel supply is a risk that also needs to be anticipated to prevent delays in project commissioning. It appears that technologically complex projects like a power plant require the involvement of an experienced EPC contractor and reliable power equipment manufacturers to manage the project.

3.3 Operation Performance Analysis

Investigation of operating performance compares the operational reliability of the power plant and is measured as the equivalent availability factor (EAF), as previously defined. The study also evaluates greenhouse gas emissions using an emission factor (EF). Table 2 summarizes calculations of the EAF and EF. The input data used for the EF computations is provided in Appendices 1 and 2. The EAF indices from the case study projects were summarized from six annual power plant performance reports from the Java-Bali Dispatch Centre from 2007 to 2013.[46,47,48,49,50,51] The Java-Bali Dispatch Centre automatically records the operational performance of all power plants that are connected in the Java and Bali electric grid, including the case study projects.

3.3.1 The Equivalent Availability Factor (EAF) Analysis

The average equivalent availability factor (EAF) detailed in Table 2 leads to the conclusion that PPP power plants had much higher reliability than traditional power plants. Of the two traditional projects, the Paiton-9 CFPP had the lowest EAF index relative to the other case study projects, with the average EAF index of just below 44%.

The EAF indices for the PPPs (detailed in Table 2) immediately reached above 80% in their first year of commercial operation. The power projects that were procured through traditional procurement had a much lower operating performance in their first year of operation—e.g., the Cilegon project and Paiton-9 project had EAF indexes of 32.4% and 26.7%, respectively.

The analysis of EAF indices in the second year of operation reveals that the two PPP projects had EAF indices that were

Table 2. Summary of project operation performance of the case study.

	EAF (%)			EF (tCO_2/MWh)		
Power plant project	1st yr	2nd yr	Average	1st yr	2nd yr	Average
Wayang Windu (PPP)	98.0	97.0	97.5	0.03	0.03	0.03
Cirebon Electric (PPP)	97.1	89.2	93.2	0.91	0.94	0.92
Cilegon (Traditional)	32.4	91.9	62.1	0.50	0.72	0.61
Paiton-9 (Traditional)	26.7	60.6	43.7	1.00	1.07	1.04

slightly lower than those in the first year of power plant operation. The Wayang Windu GTPP and Cirebon Electric CFPP projects had the second year's EAF index of 97% and 89.2%, respectively. On the other hand, the two traditional procurement projects had improved EAF indices of 91.9% and 60.6% in their second year of operation due to an increased reliability of the natural gas supply for the Cilegon CCGT and reduced technical issues in the Paiton-9 CFPP projects.[47,51]

Even though the Paiton-9 CFPP performance improved in the second year of operation, its reliability remained substantially lower than the other projects considered. These findings from the traditionally procured projects also reveal that energy supplies critically influenced operating performance.

3.3.2 Fuel Supply Arrangements

Investigation of the fuel supply arrangements in the two PPP case study projects in Table 1 revealed that they included an energy company in the project consortium. In the Wayang Windu project, there was strong service integration between the development of the geothermal resource and power plant operations. In the case of the Cirebon PPP coal-fired power project, two private coal companies participated in the ownership structure of the project. They utilized the project to secure a market for coal with a low ranking calorie from Indonesian mining operations. It provides these coal companies with comparative cost efficiency rather than transporting the coal for international buyers. The power plant has also been designed to consume coal that matches the specifications of low rank coal.

The fuel supply for traditionally procured projects is sourced via long-term contracts arranged separately by the Indonesian government with energy suppliers that are not directly connected to specific power plants. The low reliability in the performance of these projects is in part attributed to fuel supply problems. The Paiton-9 CFPP project had a mismatch between coal supply availability and power plant specifications that caused lower thermal operating efficiency.[52] The Cilegon gas-fired power plant also encountered fuel supply problems that caused delays in project commissioning and resulted in a low availability factor in the first year of operation. The project was also disadvantaged by delays in the construction of the South Sumatera–West Java transmission gas pipeline and inadequate natural gas supplies that were 45% lower in the supply volume than contracted.[53] It would appear there are advantages in directly involving fuel supply companies in the development and operation of power plants. This has been achieved in the PPP arrangements.

3.3.3 The Emission Factor Analysis

Table 2 also shows the emission factor (EF) from the four Indonesian power projects. The EF value depends on the fuel type and power plant fuel efficiency. The analysis of emission factors also demonstrates that the geothermal power plant is the most carbon-neutral power plant, while gas-fired power plant utilizing combined cycle technology may provide a better alternative than coal-based power plants in terms of carbon emission reductions. The Wayang Windu geothermal project had a very low EF of approximately 0.03 tCO_2/MWh, and the Cilegon CCGT that utilizes combined cycle gas technology had an average EF level of $0.61tCO_2/MWh$. Although the EF of the Cilegon CCGT is much higher than that of the Wayang Windu, it is substantially lower than those in the coal-based power projects. The Cirebon Electric CFPP that utilizes supercritical boiler technology had an average EF of $0.92tCO_2/MWh$, while the Paiton-9 CFPP that adopts a conventional subcritical boiler technology had an average EF of $1.04tCO_2/MWh$. Interestingly, the deviation of average EF level between these two coal-fired power projects was just above 10%, although the investment cost differences were US$390 million. The stated capital costs of the Cirebon Electric and the Paiton-9 project were US$850 million and US$460 million, respectively.

4. Discussion

The broad objectives of this article were to understand the implications of procurement strategies on the outcomes achieved from either coal or cleaner energy sources. It has been established from the literature that many emerging economies in Asia have undertaken regulatory reforms to increase private participations in energy sector development. These include private power plants in an electricity market under a single buyer electricity market model. Governments in emerging economies need to strategically select procurement methods between PPPs and traditional public procurement in order to deliver power plant infrastructure. The adoption of an in-depth case method has enabled new understandings of the complex interaction that exists between infrastructure development policy, finance, procurement methods, and environmental sustainability. These are discussed next under the headings of financing structure, construction and operation performance, and environmental performance. A summary of key performance criteria between the four case study projects is shown in Table 3.

4.1 Financing Structure

The investigation into the project financing structure adopted for the four Indonesian power projects demonstrated that finance was a critical issue, especially in PPPs where choice of the power plant combustion technology influences whether international and domestic lending markets are interested in financing the project. International financiers are attracted more to power projects that utilize renewable energy and cleaner technologies such as geothermal power, combined cycle gas turbine technology, and supercritical pulverized coal-fired technology. In contrast, conventional coal-fired power projects utilizing subcritical pulverized technology attract limited interest from international commercial banks. Therefore, financing for these projects would need to rely on bilateral credit facilities and domestic finance sources. The international finance institutions often request government guarantees when revenues generated from a power plant operation are not adequate to cover debt service payments.

4.2 Construction and Operating Performance

The case studies show that for project construction and commissioning PPPs have better time performance than traditional procurement. The Wayang Windu GTPP was completed just ahead of the contract schedule, while the Cirebon Electric,

Table 3. Summary of project performance evaluation.

Key performance criteria	Wayang Windu GTPP	Cirebon Electric CFPP	Paiton-9 CFPP	Cilegon CCGT
Broader access to project financiers	Yes	yes	no	Yes
Request loan guarantees	No	yes	yes	Yes
Ranking of timelines of construction and commissioning	1st	2nd	4th	3rd
Reliable power plant equipment	Yes	Yes	No	Yes
Competent EPC Contractor	Yes	Yes	Yes	Yes
Fuel supply security	Yes	Yes	No	No
Ranking of average power plant availability operation	1st	2nd	4th	3rd

Paiton-9, and Cilegon projects were 22%, 75%, and 31% over the contractual schedules, respectively. Delays in obtaining debt finance were the cause of time slippage in both the Cirebon Electric PPP project and the traditional Paiton-9 project. The Paiton-9 project also suffered from equipment failure that caused an additional 6 months delay. The Wayang Windu project raised debt finance from commercial finance institutions that did not include commercial terms that utilized project developers from a specific country provider. Accordingly, the project consortium had greater flexibility to choose experienced EPC contractors and select technically proven power plant equipment to develop the Wayang Windu power plant. The project has been operating at the highest availability factor when compared with the other three case studies.

The Wayang Windu PPP and the Cirebon Electric PPP had an average equivalent availability factor of 97.5% and 93.2%, respectively. In contrast, the traditional procurement approach of the Cilegon and Paiton-9 projects had an average equivalent availability factor of 62.1% and 43.7%, respectively. While use of emerging project developers is required to raise full project finance, it is critical that such developers are chosen wisely so that they do not cause a substantial drop in project performance. Evidence from the Paiton-9 project shows that it suffered from substantial completion delays and had a low level of power plant availability during the first two years of operation.

The evidence from the two PPP projects (Wayang Windu geothermal and Cirebon Electric coal-fired power project) suggests that project sponsors aligned their business interests to finance construction and ensure fuel supply security during project operation. However, traditional procurement projects suffered from a low level of sustained energy supply that led to completion delay and operation underperformance. The case studies suggest that encouraging energy company participation through a PPP mechanism offers enhanced project development and operation outcomes.

4.3 Environmental Performance

The case projects utilized different fuel and combustion technologies. It is obvious that the Wayang Windu geothermal project produces the least level of carbon emissions than the other three projects. The Cilegon project that adopted a combined-cycle gas turbine had average emission factors that were lower than the coal-fired power plant projects. The average emission factor for the Wayang Windu geothermal project was just 0.03 tCO_2/MWh, while the Paiton-9 had the highest average emission factor of 1.04 $tCO_2/$ MWh. Interestingly, Cirebon Electric, which utilizes supercritical coal-fired technology, had a higher average emission factor (0.92 tCO_2/MWh) when compared to the average emission factors of the Cilegon gas-fired project. There were slight differences seen in the emission factors between the conventional subcritical power plant and that of the supercritical pulverized boiler technology. The former produces around 10% higher carbon emissions than the latter coal technology. These environmental gains do not appear commensurate with the additional capital cost for the supercritical coal power plant. It was US$390 million more expensive than the conventional coal power plant with the same level of 660 MW power output. The benefit–cost tradeoff for the choice of the enhanced thermal efficiency of coal-fired power plant warrants review. A geothermal power plant or combined cycle gas turbine power plant may provide better options to substantially reduce carbon emission levels from electricity generation.

It is acknowledged that a limitation of the approach taken here is that these results are based on a relatively small sample of projects in Indonesia. But they are nonetheless major projects and point the way to future best practice. Similar studies need to be conducted in other developing countries to confirm our findings.

5. Conclusions

This article has reviewed the international literature relating to mechanisms to encourage investment in Asian power generation. An in-depth analysis was then conducted of four Indonesian case study projects to ascertain the relationship between finance, fuel types, choice of technology, and environmental expectations. It has shown that PPPs can produce appropriate outcomes based on the assessment of project construction and commissioning time performance, project financing structure, operational reliability, and environmental performance.

The case study investigation found that power projects in an emerging economy such as Indonesia generally rely on a significant proportion of finance from international markets to be viable, and attracting such finance is often predicated on the selection of appropriate power plant technologies and fuel type. Many international financiers incorporate environmental sustainability as a consideration for making investment decisions. The case studies examined have also shown that, for PPPs, time performance and operating reliability is consistently better than for the traditionally procured power plants.

International financiers accepted the environmental performance from the supercritical pulverized boiler technology even though it was only marginally better than conventional coal technology (0.1 tCO_2/MWh). The supercritical pulverized boiler technology carries a high cost premium (plus US$390 million for 660 MW) compared to conventional subcritical pulverized boiler technology. Further consideration of geothermal and natural gas power technologies is warranted to achieve an optimal environmental/financing outcome.

In summary, it is concluded that PPPs are an appropriate method to procure power plant projects and that they appear to be delivered in a timelier manner than traditional projects. More importantly, PPPs have substantially better performance than traditional projects in terms of availability during the first years of operation. Attracting finance to Asian power plant projects is enhanced by careful consideration of environmental factors including the choice of fuel type and the combustion technology.

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Appendix 1: Net Electricity Outputs and Fuel Consumption on Each Power Plant Case Study Projects

Year	Fuel type	Fuel specification	Wayang Windu	Cirebon Electric	Cilegon unit 1	Cilegon unit 2	Paiton-9
1st year		Net electricity output (MWh)	952,870	2,559,566	*	*	1,510,407
	High Speed Diesel oil	Consumption (liter)	0	0	0	0	7,329,338
		Net Calorific Value (TJ/Gg)	–	–	–	–	42.42
	Coal	Consumption (ton)	–	1,353,120	–	–	903,495
		Net Calorific Value (TJ/Gg)	–	18.50	–	–	17.87
	Natural gas	Consumption (MMBtu)	N/A	N/A	*	*	N/A
		Net Calorific Value (TJ/Gg)	–	–	–	–	–
	Geothermal**	Steam (tons)***	7,221,067	N/A	–	–	N/A
2nd year	Net electricity output (MWh)		960,802	4,482,863	595,275	453,997	1,846,750
	High Speed Diesel oil	Consumption (liter)	0	0	0	0	1,395,502.2
		Net Calorific Value (TJ/Gg)	–	–	–	–	37.67
	Coal	Consumption (tons)	N/A	2,381,923	N/A	N/A	1,194,847.3
		Net Calorific Value (TJ/Gg)	–	19.08	–	–	17.87
	Natural gas	Consumption (MMBtu)	N/A	N/A	8,046,533	5,250,234	N/A
		Net Calorific Value (TJ/Gg)	–	–	34.06	29.14	–
	Geothermal**	Steam (tons)***	7,281,178	N/A	N/A	N/A	N/A

Notes: *No publicly available information regarding fuel consumption for the first year operation of the two units of the Cilegon CCGT project was discovered. Instead, the calculation of the power plant emission factor was based on the public disclosure of total carbon emission and net electricity output that was 371.9 tons of CO_2 emission and 742 MWh, respectively.[54]
**Geothermal CO_2 emissions from the steam production is calculated based on the Wayang Windu project document for Clean Development Mechanism.[31]
***Estimated value is based on steam production per MWh in the Wayang Windu project document for Clean Development Mechanism.[31]

Appendix 2: Default CO_2 Emission Factor for Each Combustion Type Power Plant*

Fuel Type	Effective CO_2 emission factor (kg/TJ)
HSD (High Speed Diesel)	72,600
Natural gas	54,300
Coal	92,800

Note: *Source: IPCC 2006 Volume 2 Energy, table 1.4, pp 1.23–1.24.