Waste Management Cost Impacts on Project Finance: A Case Study of Solar Photovoltaic Rooftops in Thailand

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The IAFOR International Conference on Sustainability, Energy & the Environment – Hawaii 2017
Official Conference Proceedings

Abstract
The royal government of Thailand announced promotional policies for solar photovoltaic (PV) roof mount. The feed-in tariff policy of three project scales (small <10kW, medium 10-250kW and large 250-1000kW) has been granted to the applicants for the duration of 25 years at 6.96, 6.55 and 6.16 Baht (0.18, 0.17 and 0.16 Euro), respectively. However, there is no regulation on waste generated from solar PV project that will lead to environmental effect especially at the decommissioning phase. The effect of waste handling cost on the project finance has been analyzed using Thailand's circumstance data in 2015. Cash flows of 54 cases have been calculated along with other financial parameters. The results indicated that the most profitable case for small scale is disposal to existing land filled (IRR 13.01%, NPV 260,718.32 Baht, and BCR 1.19). In same trend, the highest return case for medium scale is disposal to existing landfill (IRR 14.34%, NPV 11,789,246.01 Baht, and BCR 1.37). For large scale, waste handling method generating the highest yield is waste incineration (IRR 14.27%, NPV 43,458,050.35 Baht, and BCR 1.36). Sensitivity analysis indicated that the project return of small, medium, and large scales would be below the benchmark value, 12.63% calculated from the ROE of the power producing companies in the national open market, at 5%, 10% and 10% income reduction, respectively. The financial results are used in predicting the designated solar PV waste, which requires proper policies in order to enforce and encourage responsibility of relevant parties.

Keywords: Solar Rooftop, Financial Analysis, Waste Management, Photovoltaic

Introduction

The electricity requirements of Thailand were rising up continuously reflecting from historical record of gross energy generation requirement. It was reported average energy requirement of Thailand during 2002-2012 was increasing 5% (Energy Policy and Planning Office, Ministry of Energy, Thailand, 2013). Regarding expansion of energy requirement, Thailand's electricity productions still relied on natural gas that was used at 71.1% of the generation in 2011 (Energy Policy and Planning Office, Ministry of Energy, Thailand, 2013). In case of nature gas shortage, the main production would be switched to other sources of energy which had an effect on electricity prices or environmental problems. For example in 2011, to compensate amount of electricity generated by using natural gas, around 21,790 million liters of fuel oil will be burned to generate same amount of heat which will be continuously converted to be electricity (Intergovernmental Panel on Climate Change, 2006). This example clearly indicated that Thailand would be facing with energy insecurity if main proportion still depends on natural gas (Cabalu and Alfonso, 2013).

Renewable energy would be a solution to increase domestic energy production that would improve energy self-dependence. Ministry of Energy of Thailand has announced 10 years of energy plan, the Alternative Energy Development Plan (AEDP) 2012-2021, to expand proportion of renewable energy up to 25% of net energy consumption or 25,000 ktoe in 2021. The plan has been updated in 2015 named AEDP2015 focus on promoting energy production by domestic renewable energy resources. To achieve the target, Government of Thailand announced various supportive policies for renewable energy such as giving premium electricity tariff to electricity produced from renewable energy that feeds to Thailand national grid. Particularly when focusing on one of proven technology like Solar Photovoltaic (PV), 3,000 megawatt (MW) of solar PV will be implemented. According to the national plan, the current status of Energy Regulatory Commission's database is presenting an overall installed capacity of commissioning solar PV projects in Thailand which is around 1,298 MW and more than 1,345 MW currently is in developing phase (Department of Alternative Energy Development and Efficiency, 2016). Another 600 MW of solar communities based policy will be implemented in upcoming future (GIZ Thailand, 2014).

At the end of project cycle, the massive amount of at least 3,000 MW of solar PV that is equally to 600,000 ton of electronic waste will unavoidably be generated. The environmental preferred waste handling methods require investment and improvement on technology, infrastructure and resources that are unattractive on economic aspect. The options for the e-waste management are still opened which some guideline suggested by Energy Regulatory Commission (ERC) at the application process. Generally, the assessment of financial feasibility of solar PV project is uncounted waste management cost as the project's expenditure. In case of absorption of waste management cost by project operator, the environmental cost of solar PV project especially waste disposal cost is usually ignored by investors. Moreover, the appropriated waste management methods are not applicable for Thailand due to national circumstances such as lack of infrastructure to recycle, insufficient sanitary landfill and less concerns on waste management policy. Furthermore, almost of solar panels in Thailand are imported from

overseas which is absent of responsible agency willing to absorb the trans-boundary cost of waste generated from solar project. In the same way, the solar panel manufacturers in Thailand do not have taken-back policy due to limitation on their technology and cost.

At decommissioning phase which is potentially absent of supplier's warrantee, decadent panels may be neglected by operator due to financial reasons. The assessment on effects of each waste handling method should be conducted to plan the appropriated waste management. Therefore, this present study was aimed to propose the most suitable case and appropriate mitigation measures of solar PV rooftop scenarios with financial analysis. The finding will be useful information for decision makers about feasible economic and waste management of solar PV

Methodology

Conceptual framework

The overall income and expenses of electricity production from solar PV rooftop focusing on a main commercialize technology as crystalline was assessed which base on 2015 circumstance. To determine viability of the solar PV project, income and expenses of Thailand scenarios which comprise feed-in tariff, project debt and interest loan rate, investment cost, operation and maintenance cost and environmental cost was used in a financial analysis of each scenario. The costs occurred by waste management methods specifying as landfill, incineration, and sending back to producer were assessed and used in determination effects on the project return. The financial assessment of each waste handling option varying with size of project was performed. Schematic of conceptual framework is shown in Fig. 1.

Sources of input data

The information of 3 scales of solar PV rooftop (0-10kW residential base, >10-250kW small-medium enterprises base, and >250kW – 1 MW industrial base) in Thailand were reviewed and updated including national policy on electricity produced by renewable sources purchasing (as a main income of the project), investment cost, operation & maintenance cost, and waste management cost. The financial assessments were performed by using specific technology of solar panel mainly used in Thailand. Any expenditures of project were surveyed by using cost of solar PV from pubic information such as brochure of related companies in Thailand and international sources. Costs of the project comprised project debt and interest loan rate, investment costs, operation and maintenance costs, and environmental costs Main project revenue set as feed-in tariff rate announced in 2015. In case of no supportive policy, energy saving can be used as revenue of the project that electricity price included float time (Ft) rate from Metropolitan Electricity Authority (MEA) or Provincial Electricity Authority (PEA) was used. Another input data affected on project performance like plant load factor, solar radiation, sun hour, and etc. would be fixed as default value based on Thailand scenario.

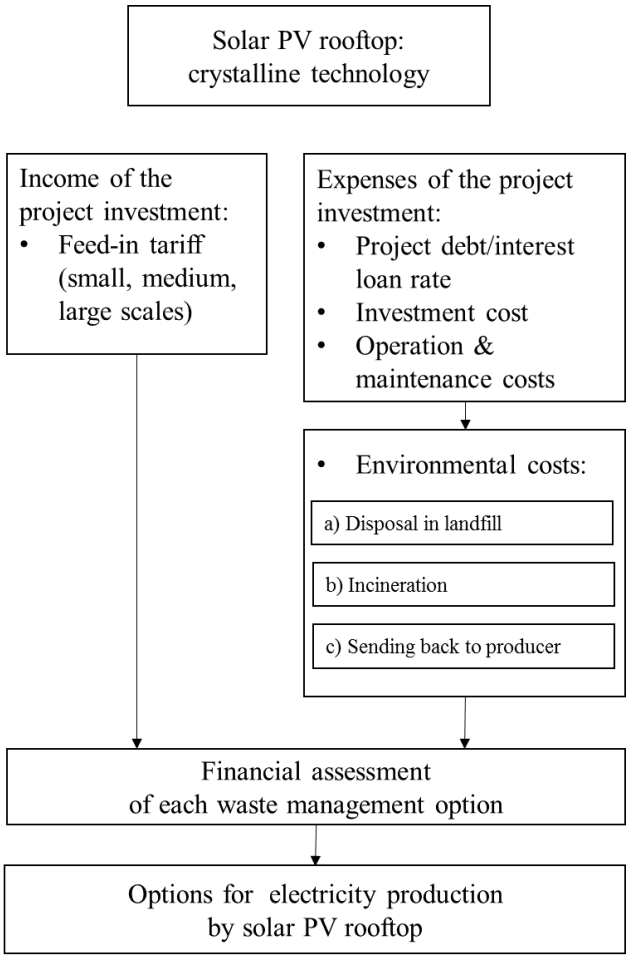

Figure 1 Schematic framework for investigating most suitable option for electricity production by solar PV rooftop with financial analysis

Financial Assessment

The first analysis in this study focused on estimating cost of waste management and its effect on project's return. Project's equity internal rate of return (equity IRR) (Blasberg, et al., 1991; Delmon, 2009) and net present value (NPV) (Welch, 2009) of each scenario were calculated. Then, the average return on equity (ROE) of all electrical companies that listed in stock exchange of Thailand was used as financial benchmarking (Delmon, 2009). The results of IRR and ROE were used to calculate break through event test of main parameters (FiT rate, base tariff rate and investment cost) which aim to identify effect of main parameters on equity IRR and NPV. The sensitivity analysis of FiT, one of tools using for trying out different assumptions to see how sensitive the IRR and NPV is, was used to indicate effect of its change to viability of the project (Welch, 2009). In this study, the main project's income as FiT rate and project's cost will be varied at different level as 5, 10, 15 and 20 percent.

Some parameters affecting on project cash flow were fixed including debt equity ratio, tax rate and loan interest rate and installment period. Debt equity ratio was fixed at 50:50

(UNFCCC, 2011). Tax rate followed the current of the Board of Investment of Thailand which giving tax promotion scheme for renewable project at 0% for 0-8 years, 15% for 9-13 years and 30% for 14-25 years over the project life time. The average of Minimum Loan Rate (MLR) of commercial banks registered in Thailand was used as loan interest of industrial base project with amortization type. The average of Minimum Retail Rate (MRR) of commercial banks registered in Thailand was used for loan interest of home and SME base project. The project scenarios were varied for 3 main parameters as scales, waste handling methods, and income of the project. All of 54 combination scenarios are summarized as Table 1.

Table 1 Fifty-four combinations of scales, three of waste handling methods, and income and cost of the PV rooftop project

	Solar PV technology: Crystalline																	
	0-10 kW (residential base)																	
Waste handling methods	Disposal to existing landfill						Send back to producer						Incineration					
Income & Cost	Sensitivity level (%)					Energy saving	Sensitivity level (%)					Energy saving	Sensitivity level (%)					Energy saving
	0	5	10	15	20		0	5	10	15	20		0	5	10	15	20	
Combinations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Scales	**10-250 kW (SME base)**																	
Waste handling methods	Disposal to existing landfill						Send back to producer						Incineration					
Income & Cost	Sensitivity level (%)					Energy saving	Sensitivity level (%)					Energy saving	Sensitivity level (%)					Energy saving
	0	5	10	15	20		0	5	10	15	20		0	5	10	15	20	
Combinations	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Scales	**250 kW - 1 MW (industrial base)**																	
Waste handling methods	Disposal to existing landfill						Send back to producer						Incineration					
Income & Cost	Sensitivity level (%)					Energy saving	Sensitivity level (%)					Energy saving	Sensitivity level (%)					Energy saving
	0	5	10	15	20		0	5	10	15	20		0	5	10	15	20	
Combinations	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

Gaps identification is a comparison between ROE and IRR results of each combination in topic of IRR, was used to indicate gap of financial performance and benchmark. The results of gaps identification presented the requirements support of appropriated waste management of each scenario. Break through event test, an analysis for identification the effect of cash flow changing on the IRR, was performed and aimed to identify changing level of main parameters that can adjust IRR to reach the benchmark.

Research Finding

Project revenue

For energy saving cases (off-grid mode), the electricity-selling rate and floated time (Ft) rate for Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) have been used as the project revenue in term of saving expense because generated electricity can be used internally. The base electricity tariff with concerned peak and off-peak rate are included in the calculation. For the other cases, the promotion scheme has been applied. The current purchasing rate announced by Energy Policy and Planning Office, Ministry of Energy, Royal Thai Government (EPPO) has been used in financial analysis as feed-in tariff rate (FiT). The FiT rates of small, medium and large scale are 6.96, 6.55 and 6.16 Thai Baht per kilowatt hour (THB/kWh), respectively. The information has been used in calculation of gross project income which is pre-tax and not reduced by other project expenses (Table 2).

Table 2 Key parameters of input data for project income calculation

Parameters	**Value (THB/kWh)**
Feed-in tariff (small)	6.96
Feed-in tariff (medium)	6.55
Feed-in tariff (large)	6.16
Peak rate (small)	3.6246
Off-Peak rate (small)	1.1914
Peak rate (medium)	2.695
Off-Peak rate (medium)	1.1914
Peak rate (large)	2.695
Partial rate (large)	1.1914
Electricity rate for large scale	132.93
Average Ft rate of year 2015	0.5282

Remark: Small (<10kW), medium (>10-250kW), and large (>250-1000kW)

Investment cost

Twenty-four service providers in Thailand have been identified comprising of two individual and twenty-two corporate service providers. Most of technologies have been fixed by services providers as crystalline module and electrical inverters that registered with the electricity authority. All of the published solar rooftop system was prices based on lump sum per Watt basis. An option for adjustment of each project component was rarely available. Only nine services providers has disclosure their prices per Watt consisting of 4 small scale, 2 large scale and 3 of unspecific. The average values were used 60.0, 56.7 and 53.4 THB/Watt for small, medium, and large scale respectively.

Regarding collected information, the investment cost was ranging and depending on the project' details. The factors should affect project cost were 1) size of the project; if the

project is too small or retail, the prices per Watt will be higher compared with the bigger project scale 2) type of services provider; there are some gap between the individual and large firm services provider which there are not all cases that individual services provider is more expensive and vice versa, and 3) the grade of the project components; the main cost of the project is the solar module but others are still effect on the cost.

Not only the different on the price, after sale services were also different between the type of service providers. The project owner may choose the cheaper option that may not include the after sale services. In addition, the project life time is long with minimum at 25 years, the small service provider may exist to facilitate project owner when the decommissioning period has come. There is no manufacturer in Thailand advertised about taking back policy or responsible on the waste during the time of survey. There is a possibility that if the waste handling program has implemented, the cost of the project would be higher.

Financial cost (Lending rates)

The financial cost is mainly occurred by lending rates. Regarding the financial assumption of 50/50 as debt/equity, it has been fixed as interest rates. The interest rate is the rate of return or amount of money that borrowers agree to pay back the creditors, as per agreement. The lending rate is comprised of 3 main rates as follows; Minimum Lending Rate (MLR) (or Minimum Loan Rate) refers to the interest rate at which the lending commercial bank charges its most creditworthy major borrowers on loans with pre-specified repayment; Minimum Overdraft Rate (MOR) refers to the interest rate at which the lending commercial bank charges its most creditworthy major borrowers on overdrafts, and Minimum Retail Rate (MRR) refers to the interest rate at which the lending commercial bank charges its most creditworthy retail borrowers on loans. This rate, when used in conjunction with the MLR, reflects the difference in risk premium between major and retail borrowers. (Bank of Thailand, 2016)

Regarding the project scheme, MLR is applicable for large-scale project and MRR is applied for medium and small-scale project. The lending rates of 19 commercial banks registered in Thailand have been published by Bank of Thailand and exhibited average at 7.09% and 8.39% for MLR and MRR, respectively (Bank of Thailand, 2016). Recently, the local banks are more familiar and confident to provide commercial loans for the solar PV rooftop. The average lending rate of 2014 from 123 countries worldwide is 11.52% (World Bank, 2016). Thailand interest rate is lower than the world average value. Hence, the local project may unattractive by the overseas banks which the lending rate of Thailand have been applied for this study which aims to reflect the status of Thailand.

Environmental cost

The cost that related with waste management after end of project life has been considered as environmental cost. Regarding the assumption of 3 methods of waste handling, the waste management cost of each method is calculated as follows

• **Tipping fee** the tipping fee of each case has been calculated by assumption of maximum collecting rate at 4 kg/day and monthly lump sum price at 220 Baht referring to the draft rate for collection fee at 65 Baht and sanitary landfill fee at 165 Baht (Information Division Office of the Permanent Secretary for Interior, 2015). The amount of generated waste per watt is fixed at 0.06 Watt/kg. The amount of waste of small, medium and large scale has been calculated as 594 kg, 14,940 kg and 59,400 kg which will be required the time for collection those waste. The period has been determined at 5, 125, and 495 months, respectively.

• **Incineration fee** the rate of incinerating waste has been surveyed from the service provider that has facility of industrial waste incinerator. The rate has been fixed at 30,000 baht/ton (transportation included).

• **Shipping fee** the rate of shipping waste has been collected from the full cycle shipping agency. The rate has been fixed at 168 baht/kg without concerning about dimension of the waste.

The information used in this topic has focusing on the related cost occurred during the decommission phase of the project. The miscellanies cost during the operating project are not considered. The selected waste management options would affect the environment i.e. air pollution by incineration the solar PV waste, heavy metal leakage or over-capacity by disposal to the landfill. The related cost with the environmental restoration and remediation that might be occurred by the eliminating the waste are not included in this study. These topics should be researched in the future to scope of environmental damages and responsibility of polluters.

System efficiency and other assumptions

The Photovoltaic module degenerates by ageing of its. The yearly degradation rate of first ten years is 0.70% and next decade rate is 0.46% and more than twenty years is at 0.43%. Another project component efficiencies are directly affected the electricity yield. The international data has been used in the assessment of system efficiency. The weather conditions of Thailand might affect overall system efficiency and plant availability i.e. hot and humid climate are cause the cracking of wiring system. Furthermore, as per imported technologies from other countries, the efficiency of components from various sources are affected the overall system performance. These issues have been concerned by conducting conservative sensitivity analysis. The results of sensitivity analysis indicated that if the system efficiency affects production by 5-10% reduction the project may unattractive comparing with the benchmark value.

Other parameters are also affected the return of the project. For examples, install capacity of three different scales are set at 9.9, 249.0 and 999.0 kW. The numbers are close to cap of supportive policy at 10, 250 and 1,000 kW. Number of operation days can be varied depend on the hypothesis of the study, in this study it is fixed with entire years. Others are be categorized into 4 main groups as operating conditions, period of construction and

permitting, Maintenance and finance. These parameters are affected the electricity yield and project cash flow and it was also concerned.

Financial Assessment

• **Internal rate of return,** the calculation of 54 cases have been conducted which the maximum Internal Rate of Return (IRR) value is at 21.10% (the most profitable case) as case no.23.1 (scale; medium, waste management method; disposal to existing landfill in Thailand, supporting scheme; Feed-in tariff SME rate and sensitivity analysis; 20% cost reduction) and the minimum IRR value is at -7.37% (the most loss case) as case no. 30 (scale; medium, waste management method; send back to manufacturer, supporting scheme; non and sensitivity analysis; non).

• **Net present value**, the calculation of 54 cases have been conducted which the maximum Net Present Value (NPV) is at 68,086,401.59 Baht (the most value case) as case no.53.1 (scale; large, waste management method; incineration, supporting scheme; Feed-in tariff factory rate and sensitivity analysis; 20% cost reduction) and the minimum NPV value is at -51,669,604.99 Baht as (the most negative value case) the most case no. 48 (scale; large, waste management method; send back to manufacturer, supporting scheme; non and sensitivity analysis; non).

• **Benchmark calculation**, the average ROE of energy and utilities and power producing companies are 11.61% and 12.63% respectively. The value of 12.63% has been set as benchmark due to conservative assessment. As the benchmarking can be used as a financial justification, if the return of the project is below the benchmark value, the investor may decide to invest in open market instead the benchmarked project.

Internal Rate of Return (IRR) values of the solar PV projects are trend to be higher because the fact that the prices of the project components have been reduced, the efficiency of the system has been improved and the effect of production scale. These situations are the reasons that the project costs are continuously reduced. IRR of the solar PV projects in India vary 31.81-10.59% by the effects of interest rates at 0-13%. These values have calculated for the without storage system cases. (Prasanna, Sameer, and Hemavathi, 2014). A residential PV system in Oahu, Hawaii with conditions of 30% federal tax credit and 25 years of system lifetime is calculated at IRR 4% and Net Present Value (NPV) 2,031 USD (Richter, 2009). However, the feasible levels of the project have been impacted by the cost of waste management indicated by this study that the different methods of waste handlings are caused the lower financial indicators. The original cases that absorb the waste management costs are still achieve the benchmark which the policy maker may enforce the project to choose any less environmental effect conditions. On the other hand, confirmation that all scale would be survived with the upcoming regulation on the waste, the tolerant options that still achieve the benchmark when sensitivity analysis has been performed i.e. case no. 20, 26, 32, for medium scale; case no. 38, 44 and 50 for large scale. For small scale (residential base), the projects would not be financial attractive, in case of absorb the waste management costs with the sensitivity cases. Hence, the policy marker may consider adjusting the other supportive scheme to

enhance financial viability of the project scale, if the enforcement of the waste would be applied.

The financial results of without feed-in tariff cases are lost because project income (in term of energy saving and calculating from the base electricity tariff of Thailand) is lower than other countries. If the selling electricity rates of Thailand increase, the return of the cases would be better. For examples, small scale project (incineration case), IRR will be positive when the electricity price increases 27 percent and will over the benchmark value when the electricity price increases 2.1 times. For medium scale (incineration case), IRR will be positive when the electricity price increases 27.5 percent and will achieve the benchmark value when electricity price increases 2.29 times. For large scale (incineration case), IRR will be positive when the electricity price increases 17.7 percent and will achieve the benchmark value when electricity price increases 2.18 times. Regarding the calculations, It can prediction the solar rooftop use for energy saving will be financial attractive if the electricity cost are increase more than 2 times.

• **Gap identification,** to maximize benefit of the investment, comparison the return of the cases with the return of investment in open market by using IRR compared with ROE respectively can be used in justification of the investment. The gap between project performance and the market have to indicate which aims to analyze the financial performance of each case. The bigger gap will lead to higher of unattractive in the investment. Financial return compare with benchmarking value which were reflecting gap are shown in Fig. 2.

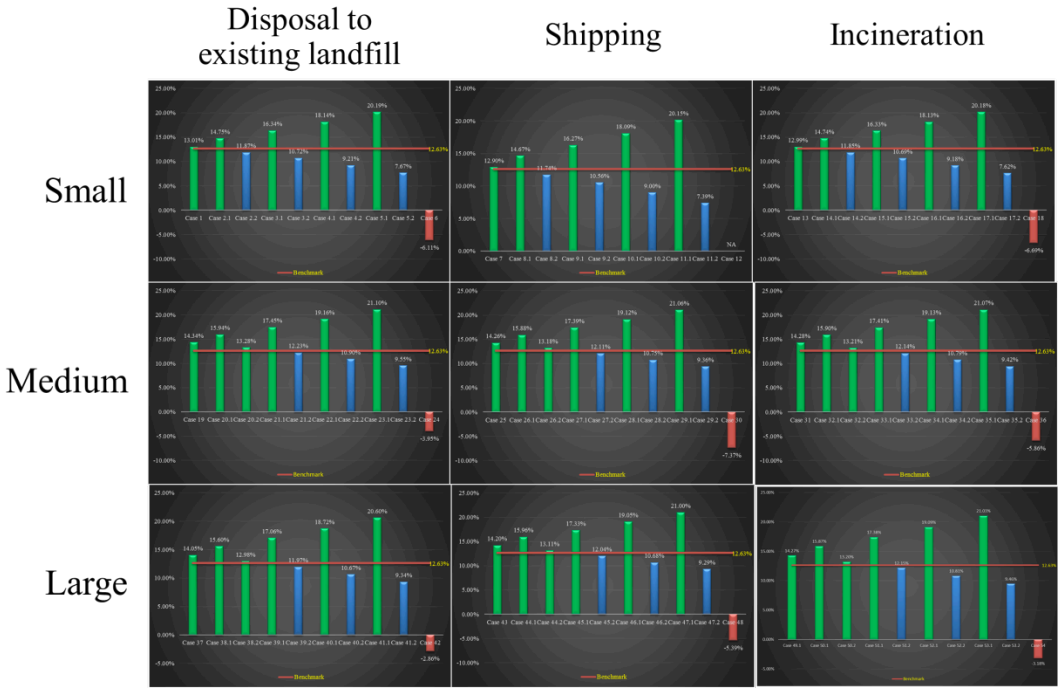

Figure 2 Benchmarking of small, medium, and large scale and comparison between three waste management methods

Conclusion

Regarding the results of calculated financial indicators, the evaluation of each project scales have been conducted to classify the justifiable of the cases. The comparison has been organized within the same project scale as per the fact that a large project could easily have higher values than a small project. The evaluation criterions used to consider worth of cases, are as follows 1) the net present value must be positive (NPV > 0), 2) the discounted present value of the benefits is greater than the discounted present value of the costs (IRR > 0) and the value have to over the benchmark of the open market (IRR > Benchmark), and 3) the ratio between the present value of the benefits and the costs must be more than one.

The results of the evaluations of each scale are presenting as follows.

• **Small scale** the different waste management costs has affected the financial indicators. The most profitable case is disposal to existing landfill consisting of IRR (13.01%), NPV (260,718.32 THB), and BCR (1.19). The other profitable waste handling methods are incineration and sending back to producer, respectively. The IRR of all cases have below the benchmarking at 12.63% when the conducted sensitivity analysis by 5% income reduction but these cases are still be commercial. All cases of the small-scale project would be lost, if the income reduces by 20% or the Feed-in tariff cannot be applied.

• **Medium scale** the different waste management costs has affected the financial indicators. The most profitable case is disposal to existing landfill consisting of IRR (14.34%), NPV (11,789,246.01 THB), and BCR (1.37). The other profitable waste handling methods are incineration and sending back to producer, respectively. The IRR of all cases have below the benchmarking at 12.63% when the conducted sensitivity analysis by 10% income reduction but these cases are still be commercial. All cases of the medium-scale project would be loss, if only the Feed-in tariff cannot be applied.

• **Large scale** the different waste management costs has affected the financial indicators. The most profitable case is incineration consisting of IRR (14.27%), NPV (43,458,050.35 THB), and BCR (1.36). The other profitable waste handling methods are sending back to producer and disposal to existing landfill, respectively. The IRR of all cases have below the benchmarking at 12.63% when the conducted sensitivity analysis by 10% income reduction but these cases are still be commercial. All cases of the large-scale project would be loss, if only the Feed-in tariff cannot be applied.

References

Bank of Thailand. (2016). Loan rates of commercial banks. Accessed 19 February 2016 from https://www.bot.or.th/english/statistics/_layouts/application/interest_rate/in_rate.aspx

Blasberg, M., et al. (1991). Manual on Project Finance Handbook for the Application of Financial Instruments in Economic Development Projects of the Friedrich Ebert Stifung : Devarsons, New Delhi.

Cabalu, H., & Alfonso, C. (2013). Energy Economics and Financial Markets. *Springer-Verlag*, Berlin Heidelberg.

Delmon, J. (2009). Private Sector Investment in Infrastructure Project Finance, PPP Projects and Risk 2nd edition The Netherlands : Kluwer Law International.

Department of Alternative Energy Development and Efficiency. (2016). Thailand PV status report 2014-2015. Accessed 11 July 2016 from http://www.dede.go.th/ebook/B0196/index.html

Energy Policy and Planning Office. (2013). Energy Statistics of Thailand 2013. Accessed 18 May 2015 from http://www.eppo.go.th/info/cd-2013/Energy%20Statistics%20of%20Thailand%202013.pdf.

GIZ Thailand. (2014). Project Development Programme (PDP) South-East Asia : Thailand pushes solar with new policies and programmes; FiT for solar farms / more capacities for residential rooftop / new solar community scheme. Accessed 18 May 2015 from http://www.thai-german-cooperation.info/download/20140901_solar_policy_briefing_DEDE_GIZ.pdf.

Information Division Office of the Permanent Secretary for Interior. (2015). Summarization of daily news. Accessed 11 July 2016 from http://www.commandcenter.moi.go.th/moiapp/user/prapp/GRPPicturePost/LT570038_LR5800857_FL58063225.pdf

Intergovernmental Panel on Climate Change. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Vol. 2 Energy). Accessed 18 May 2015 from http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html.

Prasanna, M.G., Sameer, S.M. & Hemavathi, S.G. (2014). Financial analysis of solar photovoltaic power plant in India. *Journal of Economics and Finance*, 9-15.

Richter, J. (2009). Financial analysis of residential PV and solar water heating systems. Accessed 15 June 2016 from https://www.michigan.gov/documents/dleg/Thesisforweb_283277_7.pdf

United Nations Framework Convention on Climate Change, Clean Development Mechanism-Executive Board. (2011). Guidelines on the Assessment of Investment Analysis. EB 62 report, annex 5:1-12.

Welch, I. (2009). Corporate finance: an introduction. Pearson Education, Boston, USA.
World Bank. (2016). Lending interest rate (%). Accessed 15 June 2016 from http://data.worldbank.org/indicator/FR.INR.LEND

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