Journal of Electrical and Electronic Engineering
2015; 3(1-1): 1-12
Published online October 16, 2014 (http://www.sciencepublishinggroup.com/j/jeee)
doi: 10.11648/j.jeee.s.2015030101.11
ISSN: 2329-1613 (Print); ISSN: 2329-1605 (Online)

Risk management methods applied to renewable and sustainable energy: A review

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To cite this article:
Lee Cheuk Wing, Zhong Jin. Risk Management Methods Applied to Renewable and Sustainable Energy: A Review. *Journal of Electrical and Electronic Engineering.* Special Issue: Sustainable and Renewable Energies and Systems. Vol. 3, No. 1-1, 2015, pp. 1-12.
doi: 10.11648/j.jeee.s.2015030101.11

Abstract: Renewable energy policy has always been recognized as a major incentive to the growth of renewable energy and market. In particular, in the last decade, renewable energy sources are considerably increased due to the supportive renewable energy policy worldwide. Policymakers keep on updating and revising policies in response to market changes and advances in technologies. At the same time, policymakers have shifted their perspectives from cost and benefit to risk and return so as to align with investors' perspectives. As a result, risk management has to be kept accordance with the changing policy of renewable energy. The dynamic process is important to make certain that major risks are not unattended and managed. The intent of the research is to provide stakeholders in renewable energy projects, including policymakers, financiers, developers and risk management instrument providers, a thorough review of risk management of renewable energy policy and to better define those risks so that they can be adequately mitigated to attract future investment. Five major risks which include market, credit, operational, liquidity and political risks associated with renewable energy developments and markets have been identified. Particularly, renewable energy policy risk is investigated and commonly used risk management tools are reviewed and proposed to address the associated risks and uncertainties faced by financers, developers and investors. It is also intended to setup a place for stakeholders to start, either when they want to replicate current, or are trying to develop new, workable risk management measures for renewable energy policy.

Keywords: Renewable Energy, Renewable Energy Policy, Risk Management

1. Introduction

Over the last decade, the growth of renewable technologies is tremendous. By 2012, the renewable energy industry was investing $244 billion annually [1]. Around the world, developed and developing countries are continuously seeking to boost renewable energy investment. The development of renewable energy is important to address concerns about climate change and energy diversification [2]. Renewable energy policy has been recognized as one of the main credits of the growth. In the absence of level playing ground, national, state and provincial policies have taken an important role in turning renewable energy resources to be more competitive [3]. Detailed design and proper implementation are always the keys to success. Consequently, policymakers continue to update and revise policies in response to changing environment. At the same time, policymakers have adopted risk and return perspectives in supporting investments, rather than traditional cost and benefit perspectives. Simply relying on the evolution of renewable energy policy, but still using the same risk management paradigm, will potentially leave risks unmanaged. Appropriate risk management instruments are undoubtedly essential to financers, developers and investors. In this paper, major merits and deficiencies of each renewable energy policy are identified. Uncertainties due to the deficiencies are individually investigated and handled with suitable risk management instruments.

This paper considers the fundamental renewable energy policies to evaluate the five key risk factors which include market risk, credit risk, liquidity risk, operational risk and political risk. Section 2 provides an overview of renewable energy policy and a classification of risks. Section 3 investigates the deficiencies of renewable energy policies and recommends some of corresponding risk management methods. Finally, discussion and conclusion are presented in Section 4.

2. Renewable Energy Policy Analysis

2.1. Renewable Energy Policy Overview

Renewable energy policy is a vital element for development and deployment of renewable energy. Policies aimed at supporting renewable energy developments are often adopted to capture a wide range of benefits. Common objectives for renewable energy policy include the following [4]-[7]:

- Reducing reliance on non-renewable energy sources
- Reducing emission of greenhouse gases and other air pollutants as well as their impacts
- Reducing environmental impacts
- Enhancing the diversification of electricity generation mixes
- Enhancing renewable energy involvement
- Enhancing competitiveness of renewable energy sources

The above objectives are designed to generalize benefits of increasing the use of renewable energy. In addition, return and risk are always the primary concerns for financers and developers [8]. To align with their perspectives, the rationales of renewable energy policies are often set to either increase revenues or reduce uncertainties [9]. National and state policies for establishing an enabling environment for renewable energy developments can be classified into three categories which are regulatory policies, fiscal incentives, and public financing [3]. The policies can be further sub-categorized into as follows:

- Regulatory policies
- Feed-in tariffs
- Utility quota obligations
- Net metering
- Obligations and mandates
- Tradable renewable energy certificates (RECs)
- Fiscal incentives
- Capital subsidies, grants or rebates
- Tax incentives
- Energy production payments
- Public financing
- Public investments, loans, or financing
- Public competitive bidding

Feed-in tariff is a policy scheme created to expand the growth of renewable energy technologies. The policy guarantees a sale price for renewable energy resources and grid access. This provides investors, including small-scale and large-scale developers, with incentives by securing the future income streams on their investment. In practical, long-term contracts are often signed and tariff is set high enough to recover the cost and earn an appropriate profit [10]. As of 2013, feed-in tariff had imposed on 71 countries and 28 states/provinces [3]. Since feed-in tariff is usually known in advance, this effectively stabilizes the profit of a renewable energy project and hence reduces the market risk faced by renewable energy developers and investors [11].

Utility quota obligation and mandate are other means to promote renewable energy developments. The policies define the minimum shares of generations that are generated by renewables or specific renewable sources so as to make sure renewable energy developments align with the national target. The policies are effective only if penalties are adequately set and strictly enforced [12]. In addition, literatures revealed that the effectiveness of assigning a renewable energy target relies on both of the framework of overall supporting policies and the design and barriers of electricity market [13]. In 2013, 22 countries and 64 countries have implemented utility quota obligation and obligation and mandate respectively [3]. Since the policies only define the minimum shares of renewable energy generations, the policies neither enhance returns nor lower risk. Investors and developers are mainly exposed to market risk.

According to the database of Renewable Energy Policy Network for the 21st Century (REN21), net metering has been adopted in 32 countries. The policy aims to support distribution-level renewable energy developments, which permits customers to offset their electricity consumptions by feeding renewable energy generation back to the grid [14]. Studies have investigated how net metering is effective for rewarding the deployment of renewable energy technologies [15]-[17]. The achievement of the policy should not be underestimated, although its target beneficiaries are small-scale developers. For an instance, Germany was dominated in small-scale renewable energy developments in 2010, 2011 and 2012, reflecting its attractive net metering [1], [18], [19]. Unlike feed-in tariff, electricity price of net metering is usually unknown to investors. The income received from net metering can only be estimated and hence developers and investors face market risk.

REC is a transferable energy certificate that is represented as every megawatt-hour generated from renewable energy technologies. Once REC is created, investors are flexible to trade via voluntary market or compliance market to gain additional revenue to finance renewable energy projects [20]. The REC market mechanism has been widely promoted as the solution to drive renewable energy development and investment [21], [22]. According to the database of REN12, RECs have been applied in 26 countries in which the majority is in Europe lately. Similar to net metering, developers and investors face market risk due to the price uncertainty from the sale of RECs [23]. In addition, they also face liquidity risk depending on the type, size and regulation of exchange REC market as well as the activeness of market participants [24].

While high upfront costs of renewable energy developments are usually the most significant barrier for investors and developers, even in the occasion that the project is economically feasible in a long run [25], [26]. Several renewable energy policies are designed to address the high upfront cost issue, which include capital subsidies, grants, rebates, investment tax credits and loans. Capital subsidies, grants or rebates are direct cash incentives provided to renewable energy developers while investment tax credits are indirect non-cash incentives. These policies are one-time incentives and effectively reduce the upfront costs as well as the levelized cost of energy (LCOE) [27].

Instead of providing a one-time incentive, loan programs are revolving and can be used to support renewable energy developments again. Therefore, although the effectiveness of LCOE reduction is lower comparatively, it is treasured by policymakers. Energy production payment and production tax credit are other policies to increase earnings. The former is a direct cash incentive to one unit of renewable energy generation [28] while the latter is tax credit to one unit of renewable energy generation [29]. These two policies aim to reward developers based on projects' performance. Similar to capital subsidy, grant or rebates and investment tax credit, these policies effectively reduce the LCOE. In effect, government subsidies, grants and rebates are less efficient compared to tax incentives. The reason is that government subsidies, grants and rebates are often biased by the ideological positions of the responsible politicians and by the short-term economic benefits of undertaking the project, which ignore the social impact on the entire country and the actual risk-return trade-off of the project [30]. Under the policy frameworks, developers and investors are mainly exposed policy risk and market risk.

Public competitive bidding is a tendering system by which construction and operation contracts of specific quantities of renewable capacity are awarded [31]. Investors and developers are invited to enter into a bidding process. In general, the winner will be the project developer that satisfies the descriptions and requirements of tenders with the lowest bid. A long-term contact is often rewarded. A detail example is shown in [32]. To be successfully implemented, strict development requirements need to be imposed on bidders to avoid price dumping and shortfalls or delays of developments [33]. In a typical bidding scheme, price is the most important determinant. Therefore, market risk is most likely faced by developers and investors.

2.2. Types of Risk

Table 1. *Risk Type and Sources of Risk*

Risk Type	Sources of risk
Credit Risk	Default of renewable energy projects Non-performance of renewable energy projects
Market Risk	Low capacity factor Low connection rate Low dispatch priority
Operational Risk	Discontinuous electricity output Volatile electricity output Outdated operating paradigm of the grid
Liquidity Risk	Non-existence of secondary market Long payback period
Political Risk	Unstable renewable energy policy

The main categories of risks exposed to renewable energy developments and markets are market risk, credit risk, liquidity risk, operational risk and political risk. The main sources of each risk type are summarized in table 1.

Credit risk defined as the risk that a borrower will default by failing to repay principal and interest in a timely manner [34]. Due to default or non-performance of renewable energy project, developers may fail to make required payments. Security agreement is one of the risk instruments to mitigate the credit risk [35]. The security requirement can be fulfilled in many ways, including a parent or affiliate guarantee, a stand-by letter of credit or a direct equity contribution. If default or non-performance occurs after the renewable energy project is developed, the developer releases this security and forfeits all rights to the project. Debt financer then becomes the project owner, with access to the power and any revenues generated by the project. Credit default swap (CDS) is another risk instruments to mitigate the risk [36]. CDS is a specific kind of counterparty financial agreement which provides credit risk protection. It functions like an insurance policy. In the event of default or downgrade, the buyer of the CDS receives a payoff from the seller. In general, the seller of the CDS receives payment from the buyer regularly to compensate for providing protection. Therefore, project developer can subscribe a CDS to protect themselves in case of default. To assess the protection needed, risk managers often quantify the credit risk by analyzing the probability of default, loss given default and exposure at default [37].

Market risk refers to the potential loses amount due to market movements. A capacity factor is the ratio of its actual output to its full capacity over a period of time. Typically, capacity factors of renewable energy are lower than traditional energy sources because of intermittent nature and idle capacity [38]. As a result, the amounts of renewable energy generation are often unpredictable and it causes substantial risk to investors. A low capacity factor adversely impacts on the stability of future income stream from renewable energy project. Low connection rate and low dispatch priority further reduce the competiveness of renewable energy projects and result unstable electricity sales [39]-[41]. Hedging instruments, such as derivatives and forwards, are commonly used to transfer market risk and lessen the impact on business [42]. Further measures to mitigate market risk include improving connection and dispatch policies [43], [44].

Broadly speaking, operational risk is the risks resulting from breakdowns in people, systems and internal processes. Operational concerns include personnel, equipment, testing, commissioning, operation and maintenance. History tells us that operational risk can create great impact to society and economic loss [45], [46]. As mentioned before, most of sources of renewable energy technologies are intermittent and volatile in nature that creates many problems in the operational aspect. Also, outdated operation paradigm of the grid has hindered the full potential of renewable energy projects and cause operational problem [47]. A good illustration of the problem is the situation for wind energy providers in China. Due to variability and lack of updated operation paradigm, an average of 20 to 50 percent of wind power is curtailed and subsequently not connected into the national electric grid in 2011 [48]. Catastrophe bond is one of risk management tools to transfer the operational risk to bond investors. Catastrophe bonds are risk-linked securities. It allows investors transferring a specified set of risks to the bond sponsor, such as natural disasters [50]. Renewable energy developer can utilize the bond to secure lower-cost protection from capital market. In the event of corresponding operational failure, risk is transferred to bondholders and hence developer is protected [51]. A typical and comprehensive operation risk management model can also mitigate the operational risks [49]:

- Evaluates and quantifies operational risks
- Implement appropriate risk management tools and frameworks
- Monitors the operational risks
- Investigate the causes of expected and unexpected loss events based on probability of occurrence
- Evaluate the trends, correlations and patterns of the operational risks
- Evaluate the potential losses from operational risk and impact on revenue and investment

Funding liquidity risk and asset liquidity risk are two main streams of liquidity risk concerning renewable energy development and market. Funding liquidity risk refers to the capability of a firm to access financing and capital sources to meet its liabilities while asset liquidity risk refers to the capability of a firm to trade and realize its asset on existing market at the fair value. Renewable energy investment generally requires long investment period. For an instance, the average payback periods for small (20-50kW), medium (100kW-500kW) and large (500kW-5MW) wind turbines with feed-in tariff are 12, 8 and 3 years respectively [52]. In the meantime, secondary market is seldom existed. Developer and investors are difficult to sell the asset. Therefore, liquidity risk is always a big concern in renewable energy development and investment. Debt financing and renewable energy pooled funds are means to solve the liquidity problem due to non-existence of secondary market [20], [53]. Further measures to mitigate liquidity risk include improving project revenue and improving renewable technologies. An effective liquidity risk management model can also mitigate the liquidity risks, which should have the following key factors [54]:

- A well-defined risk governance framework
- A sound liquidity management practice
- A prudent risk liquidity risk analysis, control and monitoring

3. Risk Management of Renewable Energy Policy

3.1. Renewable Energy Policy Risk

Political risk refers to the risk of investment loss in a given country caused by changes in policy or political structure. There are two main categories of political risk which are macro-level and micro-level political risks. Policy risk belongs to micro-level political risk and is defined as project specific risk. Renewable energy policy risk is the risk of investment loss in a given country caused by changes in renewable energy policy. Prospective policy risk and retroactive policy risk are two classifications of renewable energy policy risk [55]. Prospective policy risk considers the impact on the planning of new project caused by the overall uncertainty and instability of the regulatory framework, while retroactive policy risk considers the impact on the financial stability of existing projects due to policy changes. Of the two types of policy risks, the impact of retroactive changes is higher because the changes directly break down the assumptions and forecasts made by developers, financers and investors [56]. The three parties are three key parties involved in renewable energy project and they face renewable energy policy risk differently according to the timeline of project. Figure 1 shows a typical timeline of renewable energy project from the perspectives of developers, financiers and investors.

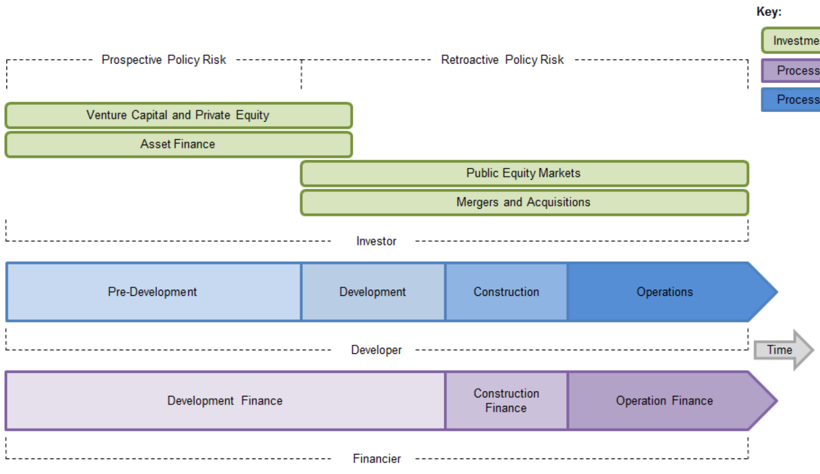

Figure 1. *A typical renewable energy project timeline for developer, financier and investor*

As shown in figure 1, developer's perspective can be divided into four distinct phases of activity. In the first phase of activity, developers consider possible market fundamentals that affect the renewable energy project's developing, constructing and operating environment. They identify market opportunities and focus on a set of renewable technologies or resources. Then developers will screen identified projects and only move forward the most promising project to the next phase. In this phase, technical analysis and financial analysis are usually performed to reveal major hurdles that deter the project execution. Renewable energy developers perform their own proprietary pro forma analysis to assess the project based on their risk tolerance and professional judgment. Renewable energy policy risk is limited because amount of money invested and time involved are not significant. In phase two, investment of capital and time required by the developer increases substantially. It is because all of the necessary documentations for the project have to be prepared and completed for the financing and construction of projects within this phase. A project development framework called SROPTTC is one of the decision making tools to access the risks connected to the renewable energy project [57]. Renewable energy policy risk is the highest, as considerable capital and time are involved. In phase three, developers start construction. The primary concern is that the developers have to deliver the service and operate the renewable energy project according to the requirements of the contract. Policy risk is high in this phase. Because amendment of renewable energy policy can significantly affect the assumptions and forecasts of the project and reversal of the project is difficult. However, many of the risks have been mitigated by the creation of asset. In the last phase, the timeline shifts from construction phase into operation phase. Renewable energy project has been commissioned and starts to operate. From the perspectives of developers, they have developed the renewable energy project capable of operating at the requirements of the contract. From then on, developers are responsible to operate and maintain the renewable energy project in accordance to the contact. Since the project approaches to the end of its planning horizon, the effect of policy amendment decreases. Therefore, policy risk decreases gradually.

The financier's perspective can be divided into three sections which are development finance, construction finance and operation finance. In the first phase, it represents the most speculative phase. In the event a deal is not completed, financiers face the risk of total investment loss. Since this phase is highly speculative, debt is often not available. Most of the capitals for development finance are come from the developers and other equity investors. Similarly, in the event policymakers amend renewable energy policy in ways that adversely impact the completion of deal, financiers face the risk of total investment loss. Hence, renewable energy policy risk is the highest in this phase. In the second phase, it represents the total capital cost of a renewable energy project. Because many of the risks have been mitigated by the creation of asset, equity and debt financing are usually provided at the construction phase. Policy risk is still high, but is dropped due to the backup of asset. In the last phase, it represents the operation finance of a renewable energy project. The high risk project has been transformed to a stable asset that is not exposed to development and construction risks anymore. The effect of policy amendment and policy risk decrease gradually.

There are four main categories of investments throughout the process: venture capital and private equity, asset finance, public equity markets and mergers and acquisitions by referring to figure 1 [1]. Venture capital and private equity and are renewable energy investment at the early stage. The investments are long-term and illiquid strategy [58]. The main difference between them is that private equity investors invest in mature companies while venture capital investors invest in startup companies. Hence, the expected return and risk from venture capital is generally higher than private equity. The most widely used valuation methodologies include price of recent investment, earnings multiple, net assets, discounted cash flows, discounted earnings and industry valuation benchmarks [59]. Depending on the valuation methodologies, the impact of prospective policy risk can be significant, particularly discounted cash flows and earnings. It is because the changes directly break down investors' assumptions and forecasts. Similar to venture capital and private equity, asset finance is an investment at the early stage. Internal company balance sheets, loans and equity capital are the main sources of funding. Investors generally have excessive information and knowledge to make investment decisions. Therefore, the expected return and risk are low compared to other categories of investments. Net assets, discounted cash flows and discounted earnings are commonly used valuation methods. The impact of prospective policy risk is significant for the same reason as venture capital and private equity investment. Unlike the above mentioned categories, public equity markets and mergers and acquisitions are investment at the late stage. Investment of public equity markets is publicly traded. Investors have flexible investment time horizon, high liquidity and accessible market information. The common valuation methodologies are discounted cash flows, discounted earnings, dividend discount model and earnings multiple [60]. Since these methodologies are all based on accurate assumptions and forecasts, retroactive policy changes could dampen the investment return [61]. The impact and retroactive policy risk is varied depending on business diversification. In general, the more the diversification of business is, the lessor the impact and policy risk are. Hence, a risk-adverse investor is more preferable to invest in a multi business company. Mergers and acquisitions are both strategic investment with the buying, selling, dividing and combining of entities with the aim to create synergy [62]. A merger is that two or more firms join forces for mutual benefit while an acquisition is that one firm takes control of another firm by purchasing the majority of its assets or shares. The five common categories of mergers are conglomerate merger, horizontal merger, market extension merger, product extension merger and vertical merger. On the other hand, the five common categories of acquisitions are value creating acquisition, consolidating acquisition, accelerating acquisition, resource acquiring acquisition and speculating acquisition [63]. Merger and acquisition investment are highly complicated procedures from per-deal planning, deal completion, post-deal integration and extraction of value. Although investors generally have enough knowledge and information to evaluate target firm, the valuation of synergy is difficult to be predicted and determined. The common valuation methods are discounted cash flows, discounted earnings, earnings multiple and net assets [64]. The impact of retroactive policy risk is significant, especially with the use of discounted cash flows and earnings. It is because the changes could destroy the value of synergy.

3.2. Risk Management

Table 2. *Primary Merits and Deficiencies of Renewable Energy Policy*

Renewable Energy Policy	Merits	Deficiencies
Feed-in tariff	Stable revenue streams Guaranteed profitability Guaranteed grid access Performance based incentive	Overpriced/underpriced feed-in tariff Inappropriate contract duration Delay in payment Delay in grid access Lack of degression rate Revised existing/future feed-in tariff
Utility quota obligation Obligation and mandate	Cost reduction due to competition Less government expenditures Centralized way to achieve national target Market based policy	Unstable electricity price Inappropriate obligation Inappropriate penalty Revised obligation Excessive focus on low cost renewables
Net metering	LCOE reduction Capable of driving small-scale projects Performance based incentive	Overpriced/underpriced net metering Unfair charges/fees imposed by utilities Impact on profitability of utilities
RECs	Additional revenue/LCOE reduction Market based incentive	Inappropriate market rules Issues of market risk Issues of liquidity risk
Capital subsidy, grant or rebates Investment tax credit Loans	LCOE reduction Upfront investment cost reduction Easier access to project financing	No guarantee of project performance Over/under reward Revised policies Interest rate risk (loans)
Energy production payment Production tax credit	Additional revenue/LCOE reduction Performance based incentive	Renewal uncertainty Revised policies Ineffective to debt financing and cash flow (production tax credit)
Public competitive bidding	Cost reduction due to competition Centralized way to achieve national target	Cost uncertainty Price dumping Shortfalls or delay in development

Table 2 summaries the primary merits and deficiencies of renewable energy policy. The uncertainties of feed-in tariff policy are mainly come from inappropriate tariff, inappropriate contract duration, improper implementation, improper design and unstable policy [12], [65]-[69]. Excessive price or duration leads to ineffective use of public funds and redundant renewable energy projects while underpriced or short term feed-in tariff is insufficient to attract investment and leads to deficit investment. Excessive feed-in tariff rates can also put upward pressure on electricity prices, especially if large-scale of high cost renewable energy technologies are included [70]. In addition, excessive feed-in tariffs can create heavy burden on the public budget [71]. An under developed transmission network and long delay in grid connection also affect the capacity factors and profits of renewable energy projects, which could ultimately cause projects default [72]. Yet, risks are manageable in this situation with adequate due diligence. Since the terms of feed-in tariff are usually made clear to investors in advance to develop renewable energy projects, investors are able to reach final decision based on the existing feed-in tariff. Instead, revise in feed-in tariff can create a bigger impact. In most of the time, governments reserve the final right to amend the feed-in tariffs. As a result, investors never know the exact duration of policy. An unexpected increment in feed-in tariff leads to an unnecessary competition and create an unfavorable business environment for existing investors while a sudden decrement can harm the growth of renewable energy and create an unfavorable business environment for new entrants [73]-[75]. Portfolio management is one of the tools to diversify the risks and impact [76]. Considering portfolio theory, if assets are not perfectly and positively correlated to each other, risk can be reduced via portfolio management due to diversification effect [77]. Therefore, a portfolio of generation resources, renewable energy projects or any combination is able to mitigate the risks. Another approach is scenario analysis which is a tool to ascertain probable future outcomes with the consideration of probable alternative events that can take place in the future. Investors can use the probable outcomes to minimize the uncertainty and choose the optimal solution based on their perspectives of risk and return. For instance, a scenario-based approach is applied to search the optimal decision by taking into account different feed-in tariff schemes and risk and return perspectives [78]. In addition, Monte Carlo simulations and mean-variance analysis are also applied to quantify the risk-return profiles of renewable energy projects [79]. Another mean to diversify the policy risk is to purchase political risk insurance products which are well designed to compensate the impact of policy change [55]. Concerning delay in payment and grid access, although portfolio management and scenario analysis are able to reduce the risks, supportive policy is still the best way to address the problems [10].

The primary risks connected with obligation/mandate and utility quota obligation are unstable electricity prices, inappropriate implementation, excessive development on low cost renewable energy technologies and revised obligation [12], [80]-[83]. Policies support the concept of free market and leave price unregulated, which increase market risk faced by investors [84]. Market-based approach and game-theoretic approach to model generation expansion planning in deregulated market can be used to handle the price uncertainties [85], [86]. Real option approach has also been applied to address the market risk in different renewable energy developments, such as hydropower power plant [87] solar power plant [88] and wind power plant [89]. Other problems are inappropriate obligation and penalty. The problems create dilemma for the project developers. On the one hand, project developer may face financial and practical issues, such as insufficient funding and profit, to achieve the targets. On the other hand, project developer may be fined for non-compliance with the obligation. Therefore, a balance between obligation and penalty should be well arranged by policymakers. An additional uncertainty associated is an unexpected obligation amendment. If policymakers suddenly revise the obligation and set a higher target, some of the renewable energy project developers could be compelled to develop an economically infeasible project in order to fulfill the obligation and avoid penalty. On the contrary, if policymakers suddenly lower a target, some of renewable energy generations could be redundant and eliminated due to excessive competition. Staging real option approach is a mean to tackle the problem. Broadly speaking, real option approach models the flexibility in response to changes in business environments, which includes the capability of deferring, abandon or adjusting the project so as to react with the evolution of uncertainty [90]. Rather than building a renewable energy project at a single stage, developer divides the project into different stages. At each of the stage, developer preserves the flexibility to abandon or to expand the project. This segmentation improves both the learning and risk reduction effect [91]. In addition, diversification is also a key to reduce risk exposure. A portfolio-based approach is one of the methods to diversity the energy mix by resources so as to lessen the impact due to policy uncertainty [92].

Referring to table 2, there are three main deficiencies of net metering, which include inappropriate net metering price, inappropriate implementation and negative impact of profitability of utilities [93]-[95]. If net metering is underpriced or unfair conditions, such as high minimal connection fee and high standby charge, are imposed by utilities, renewable energy developments are deterred. On the contrary, if the buyback prices are overpriced and the required amounts of buyback are too high, profitability of utilities will be threatened. Therefore, a proper implementation is essential to balance the benefits to both investors and utilities. Similar to feed-in tariff, net metering is usually known in advance. Hence, uncertainties due to overprice and underprice can be handled with sufficient risk assessments. To tackle the risk of unfair conditions, policymakers may impose regulations to protect small-scale investors. A study has shown that net metering lessened the impact on utility company in the case that the more efficient unit fails and has to be substituted by a less efficient one [96]. As a result, the issues of charging additional fees on net metering which punishes customers for choosing a more energy efficient appliance should be addressed. For example, a safe harbor provisions has been imposed in Minnesota so as to eliminate the disincentive conditions [97]. Concerning the impact of profitability of utility companies, business diversification strategy is a way to reduce the associated policy risk. Utility companies often have superiority in economies of scale and knowledge. As a result, it is easy for them to expand their business to retail level to lessen the impact. Literature shows that concentric diversification strategy is one of the business strategies [98]. For an instance, generation and transmission companies can extend their services to net metering equipment, installation and maintenance to hedge the risks.

As mentioned before, the sale of RECs advances the revenue and is able to finance renewable energy projects [20]. However, the overall contribution is uncertain and fluctuates significantly due to different REC markets, energy policies and other possible reasons. The impact can be as high as 50 percent or as low as 1 percent of total revenue from a renewable energy project [99]. Besides, demand uncertainty, supply uncertainty and price uncertainty induce additional market risk and liquidity risk [99]. In case of oversupply of RECs, market price could be dived strongly and the revenue from the sales of RECs could be slumped [100]. A study shows that these uncertainties are due to the market fluctuation as well as the lack of liquidity [101]. On the supply side, the creation of futures, forwards and derivatives markets with long-term contracts are ways to limit the price volatility of RECs. On the demand side, the creation of margin, loan or banking mechanisms are some possible means to limit the price volatility that encourage proactive investors to enter the market [102]. Inconsistent REC definition and attributes, REC ownership uncertainty and lack of REC tracking system are also part of the sources of liquidity risk [103]. Enhancement of implementation is a must to reduce the uncertainties. For examples, long-term contract is a way to reduce market risk and unbundling RECs and disaggregation of attributes are ways to reduce market and liquidity risk [103], [104]. An improvement on market rules, such as ceiling prices, floor prices and ability of short selling, can also improve the situations [103], [105]. Floor price and ceiling price are set up to fix REC at an agreed range of price if supply is too substantial or shortage to reduce market risks. On the other hand, short selling is set up to allow investors to hedge their positions and improve the liquidity of REC market.

According to table 2, risks connected to capital subsidy, grant or rebates, investment tax credit and loans are mainly come from revised policies [106], [107]. The reason is because the benefits are often known to developers ahead of renewable energy developments. Therefore, new and existing developers can easily assess the risks and take necessary measures. An unanticipated increase in incentives creates comparative advantages to new entrants. To hedge the risk, existing developers can use electricity derivatives to lock in profits [108]. Electricity forwards, futures swaps are some common hedge tools. On the contrary, an unanticipated decrease in incentives will slow the growth of renewable energy developments and creates comparative advantages to existing developers. Potential entrants are advised to perform cost and benefit analysis again to make their final decisions. Undoubtedly, the market risks faced by them are increased. An additional shortcoming for loan is interest rate risk. By definition, this is the risk to the incomes from investment due to the changes in future interest rates. Firstly, if interest rates fall, existing developers will have to pay the same amount of interest which they could actually pay less. Secondly, if interest rates fall, loan rates would probably fall. As a result, new entrants enjoy comparative advantages. To hedge the interest rate risk, developers may enter an interest rate swap to pay floating rate and receive fixed rate [109]. Another major deficiency is the unsecured project performance, as the incentives are not linked with performance. To solve the problem, policymakers may impose provisions to protect themselves, such as minimal electricity generation.

Although production tax credit and energy production payment share the same objective of reducing LCOE, energy production payment provides more benefits. Firstly, production tax credit is a tax allowance and tax basis. Therefore, it is ineffective to both cash flow and debt financing [110]. Secondly, renewable energy project developers typically do not have enough taxable income to have full advantage of the production tax credits [111]. Some investors attempted to transform the tax basis benefit into cash basis. However, cost and legal status of the transaction are doubtful. Another risk caused by the policies is renewal uncertainty. Both policies provide incentives with fixed period. In general, developers usually receive incentives during the first ten years of operation. By then, the renewal is subject to the allocation and availability of funds in every subsequent fiscal year. Therefore, it often creates a boom-bust cycle of renewable energy development [12]. A study demonstrated that renewal negotiation dynamics can enlarge the influence of policy risk over corporate investment decisions [112]. Staging real option approach, scenario analysis and tax credit planning are tools to manage the risk. By diving renewable energy development in different stages, investors enlarge their flexibilities in response to the renewal uncertainty. On the other hand, investors can apply scenario analysis to minimize the renewal risk [113]. Tax credit planning can also be applied to optimize the tax credit received with consideration of different uncertainties [114].

The deficiencies caused by public competitive bidding include price dumping and shortfalls or delay in development. The problems of dumping and shortfalls or delay in development can be addressed by enacting strict development requirements [33]. Other risk concerned with the policy is the cost uncertainty. Since contract price is determined during tender procedure, cost uncertainty is usually happened [115]. Optimization based static bidding strategies have been widely adopted to reduce the market risk [116], [117]. In practical, dynamic bidding strategies, such as sequential optimization bidding strategies and game theoretic approaches, have also been used to reduce the cost uncertainty [118], [119].

4. Future Work and Conclusion

At present, a wide range of risk management instruments are offered by private and public institutions. Specific risks which are credit risk, market risk, operational risk, liquidity risk and political risk, as discussed in Section II, have created a large demand by financers and developers for risk management instruments to mitigate the risks. The main challenges for the providers of risk management tools in supporting renewable energy developments are in the following three areas:

- Further improvement of risk management instruments and innovation in their uses to make them more effective in handling the specific risks of renewable energy development
- Expansion and standardization of the use of risk management instruments, in particular to renewable energy policy risk, to promote collaboration with policymakers, financiers and developers
- Enhanced risk management assistance to financiers, developers and investors to prepare renewable energy projects and attract private and public investments

In this paper, the big picture of market risk, credit risk, liquidity risk, operational risk and political risk of renewable energy development and market has been studied. A thorough review has been provided to stakeholders in renewable energy projects, such as policymakers, financiers, developers and risk management instrument providers. Furthermore, current range of ways in which risk management instruments can diversify, hedge and transfer renewable energy policy risk has been revealed.

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