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Measuring and Explaining Government Performance for Developing Solar Electricity Market

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Abstract--**This paper evaluates the productivity of worldwide countries for developing solar electricity market by addressing the following questions: (1) to what extent should governments further decrease their supports while maintaining the electricity utilization at the current level? And (2) to what extent should governments increase the production of solar electricity generation and decrease the emission of CO_2 air simultaneously? To comprehensively address both questions to improve energy utilization efficiencies, those of countries are evaluated by using Non-Separable DEA model (DEA measure with non-separable desirable and undesirable outputs for evaluating efficiency). This case study of 25 solar-development countries with the panel data covering the period of 2009 – 2012 reveals that pure technical efficiency of developing countries is slightly more efficient, on average, than that of developed countries. However, the total efficiency of developed countries does appear to be significantly more efficient than that of developing countries. Besides, the results of this paper point that inefficient countries could reduce their total expenditure and investment, days for getting electricity, total electricity generation and CO_2 emission in a given output and/or increase their proportion of solar electricity based on a constant input respectively to become efficient countries among their peer groups.**

I. INTRODUCTION

The implementation of renewable energy policy in most countries around the globe has been advocated to be supportive of the transformation into a low-carbon economy, a concept officially proposed in the Kyoto Protocol with a view to facing with the challenges of carbon emission. The strategies for this transformation include supporting for renewable energy, improving energy efficiency and reducing deforestation. Since the publication of the Kyoto Protocol report in 1997, this low-carbon transformation has attracted attention from scholarship, policy-makers and managers [31; 42]. In the same period, the energy crisis showed worldwide energy resources are beginning to run out, with devastating consequences for the global economy and quality of human life. For this reason, energy development associated with solar electricity constitutes an integral part of economic, energy and environmental policies. Solar energy sources and technologies were thus identified as an innovative means to moderate the impact of energy system on climate change and to decrease the dependence on foreign energy sources. This realization has led to a boost in solar energy related researches and industrial policies. Germany and Australia, for example, invested 10.3% and 14.5% of public R&D expenditures related to solar electricity[1] stimulation during the past five years[2] [29; 32].

However, even though public efforts and national finance have been invested for many years in order to speed up the research, development and demonstration (RD&D) of solar electricity, experiences from some countries show that this is a slow and tedious process [12] because there exist some key barriers in financial and technical aspects, including lack of government policy support, high capital cost and poor perception of renewable energy value. In an effort to overcome these barriers, many countries over the world have implemented a series of attractive solar electricity supports [11; 14; 59], most of which contain incentive instruments such as renewable portfolio standards (RPS), feed in tariffs (FITs) and tradable green certifications (TGCs), and service infrastructures such as banking and insurance services for establishment of solar electricity system. Previous studies have investigated the effectiveness of these attractive supports adopted at the national level for promoting solar electricity [8; 14; 33; 35; 37; 47; 51]. Most of these studies focused on the consequences and implications of the supports in order to address the most optimal supports for countries based on distinct circumstances. Although researchers refer to such supports as attractive motivations for stimulating the growth of solar electricity, their efficiency and efficacy remain unsettled due to the fact that the currently installed renewable generation capacities are far less than sufficient to meet the post-Kyoto targets.

These supports, whether incentives, infrastructures or others, depend heavily on government interventions with a view to achieving the target. Without government intervention, electricity supply planning in a dominant electricity market is chiefly profit-maximization and/or cost-minimization oriented [2]. An effective government intervention would be able to encourage more investment in solar electricity by hastening solar electricity utilization in the short term and improving national economic growth in the long term in terms of policy-markers' targets, such as *Framework of Taiwan's Sustainable Energy Policy*[3] in Tai-

[1] Here, solar electricity includes technologies related with solar thermal and solar photovoltaic.
[2] Germany: 2006 to 2010; Australia: 2007 to 2011.
[3] The framework states that sustainable energy policy needs to support efficient use of limited energy resources, development of clean energy and security of energy supply. Thus, the objectives of the framework are established as follows [4] BOE, 2012. Framework of Taiwan's Sustainable Energy Policy.:
Improving energy efficiency to decrease 20% of energy intensity by 2015

wan, *The First National Energy Master Plan for the period 2008-2030* in South Korea[4] and *the EU Directives*. In view of this situation, the less intervention it takes to achieve the targets, the more efficient a nation is, since incentive cost, energy subsidies, infrastructures are parts of governmental annual expenditure and investment. Hence, we address two systemic issues: (1) to what extent should governments further decrease their supports while maintaining the electricity utilization at the current level? And (2) to what extent should governments increase the production of solar electricity generation and decrease the emission of CO_2 air simultaneously? For such propose, a few advances have been provided data envelopment analysis (DEA) as a suitable analysis tool [13; 15] in order to compare the relative performance among worldwide energy markets.

The DEA approach assigns each country as a decision-making unit (DMU), which represents the amount by which all outputs could be increased without changing input level, or by which all inputs could be reduced without changing output terms. However, during the processes from electricity production to consumption under normal circumstances, undesirable outputs will be produced unavoidably, such as a variety of environmental pollutions. The maximum-output efficiency evaluation of traditional DEA model is not a suitable analytical tool; undesirable outputs need to be specially dealt with by expanding traditional DEA approach [19; 50; 55]. With the integration between energy policy field and efficiency evaluation field, this study investigates the government interventions of 25 nation-level markets by utilizing extended DEA approach to measure inter-country efficiency within a given period. The most important contribution of this study is a clear description of the indicators of the efficiency of government intervention for RE development. At the same time, this study details the evaluation and difference of national performance among sampled countries.

II. LITERATURE REVIEW

A. The incentives for solar electricity market

In accordance with the Kyoto Protocol, national governments recently set out aggressive RE policy suggesting that the proportion of energy should come from renewable sources to meet their policy goals such as energy supply stability, energy efficiency and carbon emission reduction. In the context of solar electricity promotion, the literature refers to building macro-generation of solar electricity as the performance of renewable electricity policy implementation. Solangi, Islam, Saidur, Rahim and Fayaz [47] note that the increasing attraction of solar electricity policies is a trend seen in different countries, and is characterized by a convenient access around the world to assessment and reference to design the suitable incentives [40]. They describe a shift in the control of energy market from the conventional energy system to an emergent renewable system where more and more countries decided to introduce attractive support instruments to sustain energy production, distribution and consumption [5; 36; 40; 47]. There are extensive studies investigating the merits of different solar electricity policy instruments: how they influence the use of solar electricity [8; 23; 34; 37]. Within the classification of supportive instruments, two dimensions of strategies have been developed. In particular, solar electricity strategies can be categorized as follows:

- Target orientation: this includes an investor-focused strategy to stimulate the installations for SE, and a generator-based strategy to encourage the generation of electricity from solar electricity.
- Method orientation: this provides a price-driven strategy offering financial support to attract the private engaging into this market, and a quantity-driven strategy authorizing the private sector to own solar electricity.

The principal drivers of the solar electricity policy utilization are government interventions and commitments in RE development. As Cansino, Pablo-Romero, Roman and Yniguez [5] have recently pointed out, part of solar electricity stimulation is due to strong government support. In order to stimulate the proper solar electricity market, countries have been keen to engage to supportive instruments, such as RPS, FITs, and TGCs. Furthermore, during recent years, it has become necessary to pay more attention to what can be described as an efficient incentive in terms of each national economic situation. Previous studies have analyzed contemporary supportive instruments using a series of criteria with a view to finding out the most beneficial instruments implemented around the world, by referring to specific countries and/or technologies [1; 53]. However, none of instruments would be satisfisaftory by itself to transform a conventional system into a renewable one with positive consequence only; some other supportive instruments, corresponding to the particular circumstances and objectives of a given country in developing the solar electricity, have to be synergized in the regulatory framework to reduce handicap in place [40; 41; 46; 47].

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and 50% by 2025;
Developing clean energy to reduce nationwide CO2 emission and to increase the share of low carbon energy in electricity generation systems from the current 40% to 55% in 2025;
Securing stable energy supply to achieve economic development goals, such as 6% annual economic growth rate from 2008 to 2012, and USD 30,000 per capita incomes by 2015.

[4] See the details of other countries in the website of International Energy Agency (IEA): http://www.iea.org/policiesandmeasures/renewableenergy/

TABLE 1. FUNDAMENTAL TYPES OF POLICY INSTRUMENTS

	Price-driven	Quantity-driven
Investor-focused	◆ Investment subsidy ◆ Tax credit ◆ Low interest / Soft loan	◆ Investment grant
Generator-based	◆ Feed in tariff ◆ Feed in premium	◆ Tradable green certificate

Sources: compiled by the authors (Cost ClarityFouquet and Johansson [8]; del Rio and Mir-Artigues [11]; Dusonchet and Telaretti [14]; Garcia et al. [20]; Oikonomou, Flamos, Gargiulo, Giannakidis, Kanudia, Spijker and Grafakos [37]; Solangi, Islam, Saidur, Rahim and Fayaz [47]

From the viewpoint of economic scholarship, the effect of promoting solar electricity emphasizes the overall economical benefit. Some studies have analyzed the economic, environmental and employment impacts of renewable energy markets in the world. A wide range of fields has been investigated in those studies in order to calculate and to predict the beneficial effects. Some studies aim to present and discuss a quantitative assessment of this new regulatory mechanisms introduced over the world, with respect to its attractiveness to investors, its effectiveness towards launching the new energy market, its cost efficiency and its guarantee to overcome invest-based risk accompanying increased expenditure of governmental investment [6; 9; 30; 43]. Therefore, the efficiency of governmental investment in a view to developing solar electricity market has attracted more attention from scholarship.

B. The infrastructures for solar electricity development

Physical and service infrastructures in relation to solar electricity market have received relatively limited attention by scholars. However, for emerging solar electricity industries to succeed, they need reliable infrastructures to enable their everyday operations and support their long-term developments. Especially, the service infrastructures and high-quality ICT infrastructures are emphasized in the area of new technologies. We differentiate the following elements [10; 16]:

- Physical infrastructures: these include communication, energy and others, such as high-speed ICT infrastructure, broadband, telephone, electricity grid network, etc.
- Service infrastructures: these are composed by knowledge and technical capacities, such as availability of scientific and applied knowledge and skills, testing facilities, possibilities for knowledge transformation, banking, security and insurance services, patent application, training, education etc.

In general, physical infrastructures for electricity supply are characterized by their large scales, inseparability and long period of operations. Ths supply of solar electricity is based on the same physical infrastructures. Therefore, it is highly likely to avoid additional costs for the private to invest in them. In this study, we would like to emphasize the importance of the service infrastructures as a basic condition for solar electricity market incubation.

C. Measuring the efficiency of governmental investment with DEA approach

For measuring efficiency, data envelopment analysis (DEA) has been applied to study a wide discipline of practical issues, including energy efficiency of national market. An evaluation of energy utility efficiency for regions in China from 2000 to 2003 has been carried out by Hu and Lee [27]. The inputs include labor, capital stock, gas oil consumption and electricity consumption, while real gross domestic production (real GDP) is the single output. Further discussion has been made by Honma and Hu [25]; Honma and Hu [26]. They assessed the relationship between extended inputs (including labor, private and government capital stock and 11 energy factors) and the same output factor, real GDP in the DEA model for evaluating the relative energy efficiency and relative productivity growth of Japanese regions through employing panel data from 1993 to 2003. From a national viewpoint, researchers have regarded energy efficiency as important relative performance among countries. Hawdon [24] employed DEA to study the impacts of policy developments simultaneously on the relative performance of gas industries among 33 developed and developing countries. Gas consumption and numbers of customers are outputs, while employment and length of pipelines are the inputs. Hu and Kao [28] investigated an environment energy index for APEC countries from 1991 to 2000 by adopting the DEA model. In their study, the inputs examined are labor, capital stock, energy consumption and CO_2 emission, while GDP is the only output.

During the process from electricity production to consumption under normal circumstances, undesirable outputs, such as a variety of environmental pollutions, will be unavoidably produced. The maximum-output efficiency evaluation of traditional DEA model is thus not suitable to be used in this situation; undesirable outputs need to be specially dealt with by expanding traditional DEA model. Fare, Grosskopf, Lovell and Yaisawarng [19] proposed the first extended DEA model to deal with the environmental efficiency evaluation considering the undesirable outputs with the weak disposability. So far most researchers have not only focused on economic and financial efficiency, but also paid attention to environmental efficiency evaluation. Zaim and Taskin [55] conducted cross-section comparisons on the production processes in the treatments of pollution emission between OECD countries by using non-parametric approach. Talluri and Sarkis [50] had summarized the applications of the DEA model in environmental efficiency research. Based on the indicators in the DEA model proposed by Esty et al.

[18], namely, their total final energy consumption, renewable energy consumption and CO_2 emissions, Zhou et al. [56] constructed a sustainable energy index to determine the efficiency of ustainable energy development in APEC countries. Zhou et al. employed the efficiency analysis method based on the environmental DEA technique and non-radial DEA model for investigating carbon emissions within several countries[57; 58]. Gomes and Lins [21] developed zero sum gains DEA to evaluate carbon emission within 64 countries with terms of considering Kyoto Protocol statement. Sozen and Alp [49] compare the distance of environmental protection efficiency between Turkey and the EU countries applying carbon emissions (such as CO_2 and SO_2) and pollutants values as the output in the DEA model. Yeh et al. [54] further integrate GDP, CO_2 emission and SO_2 emission as good and negative outputs to assess energy efficiency through representing inputs for labor, capital stock and energy consumption in China and Taiwan from 2002 to 2007.

From the perspective of promoting solar electricity promotion, the amount of electricity generation from solar resources as the efficiency is the generated capacity associated with the policy targets [13; 15; 59]. Previous studies applied the number of customers, the scope of service area and electricity sales as outputs to analyze the production efficiency of electricity distribution industry in domestic market with a view to considering productive efficiency; the input items they employed include the number of employees, circuit km of electricity network length and network losses [3; 38]. Zhou, Wang and McCalley [59] presented a bi-level optimization approach to investigate cost efficiency through measuring how much policy-makers intervene in order to achieve a goal. In comparison with their study which focuses on achieving a goal with less intervention, Deshmukh, Bharvirkar, Gambhir and Phadke [13] maintain that governments adopt efficiency policy not only to fulfill their targets, but also to improve the technology capacity to reduce the cost of solar electricity generation. Previous studies aslo argue that FITs scheme would influence the domestic fiscal burden so that the governments should amend their policy based on their economic situation to limit total subsidy for installing solar electricity deployment. However, del Rio and Mir-Artigues [11] note that under such a circumstance the limitation can encourage the use of more efficient technology in order to produce more solar electricity from the deployment of existent installations.

Overall, researchers have constructed a variety of DEA efficiency models considering desirable and undesirable outputs, including productive and technical efficiency improvement, environmental performance evaluation, pollutant emission assessment and shadow prices of pollutant estimation. As Ekins [17] argues that the price incentives are likely to be an important instrument for improving renewable energy efficiency, the RE promotion may be successful in practical terms. Thus, Ekins highlighted "How necessary are price increases to encourage behavior change (and reduced absolute levels of emissions) in a context of rising incomes?" Additionally, Song et al. [48] reviewed related studies and indicated that the results of environmental efficiency analysis are related some aspects. One important element is that they considered environmental pollutants and other undesirable outputs, associated with resources invested in the production process, which increased and or decreased with desirable outputs. They pointed out that, when the efficiency is improved by a decision-making unit, one can increase desirable outputs while reducing undesirable outputs at the same time. In fact, the previous study demonstrated that within OECD countries if the disposability for carbon emission were strictly restricted as the result of the environmental regulation, the total value of GDP would lose accompanied by the carbon emission reduction[55].

III. RESEARCH METHODOLOGY

As Rayp and Van De Sijpe [44] wrote, a evaluation measure for governmental performance does not exist. This implies that in order to identify its performance for developing RE, we first have to derive an estimate for governmental performance for RE. For this purpose we opt for the data development analysis (DEA) approach. DEA model constructs the efficiency by 'enveloping' the data according to the assumption that the production possibility set is the smallest set that satisfies convexity and free disposability, whilst containing all observed combinations of multiple inputs and outputs. Next, 'efficiency' is measured as the distance from the constructed production possibility frontier that indicates what outputs can be expanded with fixed inputs.

As a result of the awareness of environmental conservation in the modern society, undesirable outputs of production and social activities (e.g. air pollutants and hazardous wastes) have aroused strong concerns [22; 57]. Thus, the development of technology with less undesirable outputs is a crucial issue in every field of production. Researchers for this reason assume that producing more desirable outputs relative to fewer inputs and less undesirable outputs is a criterion of efficiency. In previous studies, several researchers have proposed methods for this purpose [7; 19; 21; 39; 45]. However, the maximum-output or minimum-input efficiency evaluation of traditional DEA model is not suitable to be employed in such situation; undesirable outputs need to be specially dealt with by expanding traditional DEA model. Fare, Grosskopf, Lovell and Yaisawarng [19] proposed the first extended DEA model to deal with the environmental efficiency evaluation considering the undesirable outputs with the weak disposability. Energy field studies using undesirable DEA model have been with DMUs with multiple inputs and outputs referred to the studies of Fare, Grosskopf, Lovell and Yaisawarng [19] on the application of DEA in the environment related issues.

We assume that certain undesirable outputs are not separable from the corresponding desirable outputs. Hence, reducing undesirable outputs is inevitably accompanied by the reduction in desirable outputs. Additionally, we observe that a certain undesirable output is non-separable with a certain input. In this study, for electric utilization, carbon emissions are proportional to the energy resource consumptions in the input side. Non-separable DEA model deals with this situation. For this, we decompose the set of desirable and undesirable outputs into Y^{Sg} and (Y^{NSg}, Y^{NSb}) where Y^{Sg} denotes separable desirable (good) outputs, Y^{NSb} and Y^{NSb} non-separable desirable and undesirable (bad) outputs in this study. The set of input X is decomposed into (X^S, X^{NS}) where $X^S \in R^{m_1 \times n}$ and $X^{NS} \in R^{m_2 \times n}$ denote respectively the separable and non-separable inputs. For the separable outputs Y^{Sg}, we have the same structure of production as usual outputs. However, the non-separable outputs (Y^{NSg}, Y^{NSb}) need another handling. A reduction of the undesirable outputs y^{NSb} is designed by αy^{NSb} with $0 \leq \alpha \leq 1$, which is accompanied by a proportionate reduction in the desirable outputs y^{NSg} as denoted by αy^{NSg} as well as in the non-separable input denoted by αx^{NS}.

In this study, the production possibility set under CRS is defined by

$$P_{NS} = \left\{ \left(x^S, x^{NS}, y^{Sg}, y^{NSg}, y^{NSb}\right) \middle| \begin{array}{l} x^S \geq X^S\lambda, x^{NS} \geq X^{NS}\lambda, y^{Sg} \leq Y^{Sg}\lambda, y^{NSg} \\ \leq Y^{NSg}\lambda, y^{NSb} \leq Y^{NSb}\lambda, \lambda \geq 0 \end{array} \right\}$$

We then alter the definition of the efficiency status in the non-separable case as follows.

A DMU $\left(x_0^S, x_0^{NS}, y_0^{Sg}, y_0^{NSg}, y_0^{NSb}\right)$ is recognized as efficient in this study if and only if

(1) for any α $(0 \leq \alpha < 1)$, we have $\left(x_0^S, \alpha x_0^{NS}, \alpha y_0^{Sg}, \alpha y_0^{NSg}, \alpha y_0^{NSb}\right) \notin P_{NS}$, and

(2) there is no $\left(\left(x^S, x^{NS}, y^{Sg}, y^{NSg}, y^{NSb}\right) \in P_{NS}\right)$ such that $x_0^S \geq x^S, x_0^{NS} = x^{NS}, y_0^{Sg} \leq y^{Sg}, y_0^{NSg} = y^{NSg}, y_0^{NSb} = y^{NSb}$
with at least one strict inequality.

We implement this model by the program in $\left(\lambda, s^{S-}, s^{NS-}, s^{Sg}, s^{NSb}, \alpha\right)$ under additional constraints as follows.

$$\rho^* = \min \frac{1 - \frac{1}{m}\sum_{i=1}^{m_1} \frac{S_i^{S-}}{x_{i0}^S} - \frac{1}{m}\sum_{i=1}^{m_2} \frac{S_i^{NS-}}{x_{i0}^{NS}} - \frac{m_2}{m}(1-\alpha)}{1 + \frac{1}{s}\left(\sum_{r=1}^{s_{11}} \frac{s_r^{Sg}}{y_{r0}^{Sg}} + \sum_{r=1}^{s_{22}} \frac{s_r^{NSb}}{y_{r0}^{NSb}} + (s_{21} + s_{22})(1-\alpha)\right)}$$

Subject to

$$x_0^S = X^S\lambda + s^{S-}$$
$$\alpha x_0^{NS} = X^{NS}\lambda + s^{NS-}$$
$$y_0^{Sg} = Y^{Sg} - s^{Sg}$$
$$\alpha y_0^{NSg} \leq Y^{NSg}\lambda$$
$$\alpha y_0^{NSb} = Y^{NSb}\lambda + s^{NSb}$$
$$\sum_{r=1}^{s_{11}}\left(y_{r0}^{Sg} + s_r^{Sg}\right) + \alpha\sum_{r=1}^{s_{21}} y_{r0}^{NSg} = \sum_{r=1}^{s_{11}} y_{r0}^{Sg} + \sum_{r=1}^{s_{21}} y_{r0}^{NSg} \quad (a)$$
$$\frac{s_r^{Sg}}{y_{r0}^{Sg}} \leq U(\forall r) \quad (b)$$
$$s^{S-}, s^{NS-}, s^{Sg}, s^{NSb}, \lambda \geq 0, 0 \leq \alpha \leq 1,$$

where s_{11}, s_{21}, s_{22} are respectively numbers of element in *Sg*, *NSg* and *NSb*, and $s = s_{11} + s_{21} + s_{22}$. The constraint *(a)* is added in order that the total amount of desirable outputs remains unchanged. The constraint *(b)* is added in order to restrict the expansion of separable desirable outputs in a reasonable range.

Finally, let an optimal solution of the above program be $\left(\rho^*, \lambda^*, s^{S-*}, s^{NS-*}, s^{Sg*}, s^{NSg*}, s^{NSb*}, \alpha^*\right)$, then we have $0 < \rho^* \leq 1$, and is holds that $\rho^* = 1$ *if and only if the DMU is efficient under added conditions*. If the DMU is in-efficient, it can be improved and become efficient by the projection below.

$$x_0^S \Leftarrow x_0^S - s^{S-*}$$
$$x_0^{NS} \Leftarrow \alpha^* x_0^{NS} - s^{NS-*}$$
$$y_0^{Sg} \Leftarrow y_0^{Sg} + s^{Sg*}$$
$$y_0^{NSg} \Leftarrow y_0^{NSg} + s^{NSg*}$$
$$y_0^{NSb} \Leftarrow y_0^{NSb} - s^{NSb*}$$

Furthermore, we decompose this overall efficiency into respective in-efficiencies as follows:

$$\rho^* = \frac{1 - \sum_{i=1}^{m_1} \alpha_{1i} - \sum_{i=1}^{m_2} \alpha_{2i}}{1 + \sum_{r=1}^{s_{11}} \beta_{1r} + \sum_{r=1}^{s_{21}} \beta_{2r} + \sum_{r=1}^{s_{22}} \beta_{3r}}$$

Where

$\alpha_{1i} = \frac{1}{m}\frac{s_i^{S-*}}{x_{i0}^S}$ $(i = 1, \dots, m_1)$ *(Separable inputs)*

$\alpha_{2i} = \frac{1}{m}(1-\alpha^*) + \frac{1}{m}\frac{s_i^{NS-*}}{x_{i0}^{NS}}$ $(i = 1, \dots, m_2)$ *(Non-separable inputs)*

$\beta_{1r} = \frac{1}{s}\frac{s_r^{Sg*}}{y_{r0}^{Sg}}$ $(r = 1, \dots, s_{11})$ *(Separable desirable outputs)*

$\beta_{2r} = \frac{1}{s}(1-\alpha^*)$ $(r = 1, \dots, s_{21})$ *(Non-separable desirable outputs)*

$\beta_{3r} = \frac{1}{s}(1-\alpha^*) + \frac{1}{s}\frac{s_r^{NSb*}}{y_{r0}^{NSb}}$ $(r = 1, \dots, s_{22})$ *(Non-separable undesirable outputs)*

A. Indicators

1) Electricity utilization indicators: DEA inputs

Electricity market can be organized through different governmental investment such as electricity market creation considering different resources and electricity supply infrastructure. In this study, solar electricity defines that electricity is generated only from solar irradiation through solar photovoltaic and/or solar thermal. Governments implement regulatory policy and compile the cost of incentive budget for expenditure in order to create new solar electricity market. In general terms of electricity utilization, the public infrastructure can be recognized as an important issue on the quality of electricity supply. Here, there are three approaches to measure the renewable electricity utilization. Under the first approach, for developing solar electricity, governments have introduced some supportive incentives in order to construct emergent market mechanism. In terms of RPS, FIT schemes or other incentives, all supportive activities are summed in one budget with the share of government annual total expenditure (Yamaguchi et al., 2013). Second, we employ the gross fixed capital formation as an indicator associated to invest one part of national infrastructures for electricity utilization. From the viewpoint of market operation, all electricity users have to submit application to the utility for installation and transportation for conventional electricity and/or renewable electricity inevitably. It takes amounts of time depending on the level of electricity infrastructures, including application processes, grid intensity and electricity generation and stock capabilities. Third, price indices of means of electricity production are composed of several categories including renewable energy resources, clean energy resources and conventional energy resources into one magnitude. For some major renewable markets, researchers observed that as a practical matter, the users will absorb extra expenses which are the added cost of purchasing renewable electricity and additional administrative charge from utilities. Thus, the renewable electricity market can be assumed to be maturing accompanied by the level of national income (Aalbers, van der Heijden, Potters, van Soest, & Vollebergh, 2009; Ab Kadir, Rafeeu, & Adam, 2010; [11]; [37]; [46]; [51]; [59].

Therefore, we propose to use four electricity utilization indicators as DEA inputs which are *government total expenditure (EXP), gross fixed capital formation (GFCF)*, *total income per capita (INC)* and *days required getting electricity (DAY)*. Here, *days required getting electricity* is recognized as non-separable input for measuring electricity utilization as the generation, transportation and supply need to be taken into consideration when users apply for using electricity.

2) Electricity consumption indicators: DEA outputs

The electricity utilization output indicator can be defined as economic and/or environmental indicator of activity level performed in the market. It is obvious that the higher level of development for new solar electricity market, the more tendencies toward using energy, economic and environmental indicators since in high level of development, the growth of solar electricity market makes it clear to achieve the supra-national and/or intra-national targets. Energy, economic and environmental output indicators for national level have been used frequently in literatures and in practice such as IEA survey and the Directives [18]; [22]; [26]; [37]; [42]; [48]. Here are these indicators: *gross domestic production*, *the percentage of solar electricity in total final electricity consumption*, *total electricity consumption* and *CO_2 emissions*.

(1) *Gross domestic production (GDP)*: The most comprehensive measure of national output accompanied by implementation of renewable electricity policy.

(2) *The percentage of solar electricity on total electricity consumption (PRE)*: One of the targets set by several countries is to increase the percentage of solar electricity. The percentage of solar electricity is based on the renewable energy development set by governments. For example, in renewable-advanced countries, German, Spain and France, the targets of renewable energy have to reach around 18% to 23% of total final energy consumption by 2020; in some latecomers of renewable energy markets, China, Taiwan, Malaysia and Indonesia, the targets of the percentage of renewable energy are from 10% to 24%. In general, the average of the targets has to be achieved about 20% by 2020 to 2030[5]. Here, we choose solar electricity as our target owing to the carbon emission within the lifecycle from manufacturing solar equipment to recycling used equipment nearly equal to zero. In order to reduce carbon emission, government can attract the private to install solar electricity deployment. Thus, in this study, this output is positively non-separated with undesirable outputs which we describe following.

(3) *The ratio of total electricity generation (TEG)*: A measure of electricity utilization output that includes renewable, clean and other conventional electricity. With a view to energy conservation and carbon reduction, it is expected that producing more electricity will increase government performance. Accordingly, this indicator here is recognized as a desirable output which is directly associated with carbon emission.

(4) *CO_2 emission to GDP (COE)*: The carbon equivalent of air pollutant derived from national activity. Several governments have been concerned with the impact of carbon emission; thus they must consider the carbon emission reduction through implementing renewable energy and/or advocating energy conservation. The researcher considers that undesirable outputs are not separable from the corresponding desirable outputs [52]. In this vein, reducing undesirable outputs is unavoidably accompanied by reducing desirable outputs. Therefore, the non-separability between desirable outputs and undesirable output should be taken into account in the application of the DEA model.

IV. EMPIRICAL RESULTS

Even though data on solar electricity production and investment is relatively mere, a little information is still available on productive inputs and costs for the purpose of international comparisons. This study uses country level data made available by estimating efficiency measures of the solar electricity policy among these 25 countries. This study employs seven variables as inputs and outputs. Inputs include: *EXP*, *GFCF*, *INC* and *DAY*. Outputs include: *GDP*, *PRE*, *TEG* and *COE*. This study derives our data from the World Development Indicators and the Doing Business Database of the World Bank, the Statistical Review of World Energy of the British Petroleum Company and the National Statistics of Taiwan's Statistical Bureau.

The solar electricity markets sampled in this study include 25 countries over 4 years. Summary statistics are shown in Table 1 for the solar electricity markets. For national economic development, the average percentages of government total expenditure and investment to GDP are about 42 and 22 within the given years and the standard deviations are lower than the averages, suggesting that governments put similar efforts on development. However, the standard deviations of CO_2 emissions and total electricity generation are both much higher than average, implying that some countries' CO_2 emissions and total electricity generation, for example, in 2009 are much lower than 625 tons and 399 tons while others are significantly higher.

[5] See the details of other countries in the website of International Energy Agency (IEA): http://www.iea.org/policiesandmeasures/renewableenergy/

TABLE 1.SUMMARY STATISTICS FOR 2009 – 2012 BALANCED PANEL DATA FOR SOLAR ELECTRICITY MARKETS

Variable	2009		2010		2011		2012	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
EXP (% of GDP)	42.967	11.185	42.065	11.534	41.596	11.130	41.800	11.091
GFCF (% of GDP)	21.932	7.299	21.854	6.152	21.699	6.011	21.499	6.439
INC (PPP, current US$)	28397.000	11399.219	29371.240	11809.629	30264.320	11947.616	31256.120	12492.750
DAY (days)	95.040	70.970	87.960	58.864	87.680	58.646	85.560	56.617
COE (103US$/tons)	625.033	1394.641	667.084	1537.472	694.938	1675.055	724.890	1784.326
TEG (103US$/toe)	399.057	727.953	430.909	820.581	451.245	914.814	462.070	958.018
GDP (current US$)	28641.793	16456.996	29314.991	16992.615	31873.007	19167.341	30205.423	18645.165
PRE (%)	0.002	0.004	0.003	0.006	0.007	0.011	0.011	0.016

Note: The number of DMUs from 25 countries within 4 years is 100.

Table 2 lists the correlation analysis between inputs and outputs. The correlation analysis clearly states that the correlation coefficients between outputs and inputs are almost significant. The first step of DEA model involves determining the positive/negative relationship between inputs and outputs. We here employ a Pearson correlation analysis to test for isotonicity, that is, the positive and negative directions of the relationship between inputs and outputs. Based on results of the inter-correlation analysis, the correlation coefficient between INC, EXP and PRE is significantly positive, meaning when a government gives more financial supports for development and for income, the proportion of solar electricity would be increased more; the correlation coefficient between GFCF and TEG, COE are significantly positive, meaning that with more government investments for infrastructures, the total electricity generation and CO_2 emissions would be increased more. The correlation coefficient DAY and PRE is significantly negative, meaning that more days for getting electricity supply will decrease the proportion of solar electricity.

The DEA analysis of the data presented in Table 3 has been performed using DEA-Solver software package. The efficiency scores of countries in different years (year-country) are examined by CRS (constant return to scale) assumption and VRS (variable return to scale) assumption separately. The efficiencies of countries showed that in developing solar electricity markets some countries are relatively competitive to the others.

Table 3 shows that 46 of 100 DMUs have been considered efficient (in terms of the GDP and PRE) under the CRS assumption within 2009 and 2012. In 2009, they are Austria (AUT) (The name of each country is presented in Appendix A), Denmark (DNK), France (FRA), Germany (DEU), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE) and Japan (JPN); in 2010, they are Austria, Belgium (BEL), Czech Republic (CZE), Denmark, France, Germany, Portugal, Spain, Sweden, Switzerland, Australia (AUS) and Japan; in 2011, Czech Republic, Denmark, France, Germany, Greece (GRC), Italy (ITA), Spain, Sweden, Switzerland, Australia and Japan; in 2012, they are Austria, Belgium, Bulgaria (BGR), Czech Republic, Denmark, France, Germany, Greece, Italy, Spain, Sweden, Switzerland, Australia and Japan. These 46 DMUs have been considered in this study as have high total efficiencies compared to the others as the effect markets structure has been eliminated in each year. When VRS is assumed, about three quarters of them have also been considered efficient (see details in Table 3). As expected, the VRS efficiencies, which measure pure technical efficiencies excluding effects of scale of operations, are larger than the corresponding CRS efficiencies. For instance, the CRS efficiencies of India (IND) are between 0.65 and 0.71 during the

TABLE 2.CORRELATION MATRIX FOR INPUTS AND OUTPUTS

	EXP	GFCF	INC	DAY	GDP	PRE	TEG	COE
EXP	1	-.611**	.609**	.008	.502**	.219*	-.400**	-.415**
GFCF	-.611**	1	-.557**	.179	-.444**	-.166	.806**	.829**
INC	.609**	-.557**	1	-.258**	.940**	.162	-.408**	-.435**
DAY	.008	.179	-.258**	1	-.292**	.162	.149	.165
GDP	.502**	-.444**	.940**	-.292**	1	.063	-.314**	-.345**
PRE	.219*	-.166	.162	.162	.063	1	-.073	-.088
TEG	-.400**	.806**	-.408**	.149	-.314**	-.073	1	.993**
COE	-.415**	.829**	-.435**	.165	-.345**	-.088	.993**	1

given years and their scores increase to 1 under the VRS assumption. The CRS efficiency score is lower because this country does not operate at a best possible scale size. The ratio of CRS and VRS efficiency is the scale efficiency. For example, the scale efficiencies of Mexico are all lower than 0.1, meaning that the country is not able to reach unit efficiency because it is not operating at the most productive scale size, and its present size of operations reduces its pure technical efficiency (i.e. the VRS efficiency) by 99%. When VRS is assumed, Mexico, Greece, Bulgaria, Portugal, Israel and India in some given years are considered efficient. This suggests that the CRS inefficiencies of these four countries are due to the fact that they are not operating at the best possible scale size.

The pure technical efficiencies in Italy were inefficient in 2009 and 2010 led the total efficiencies to be inefficient, but the total efficiencies in 2011 and 2012 increased to 1. It implies that the service infrastructures of sale and net metering for renewable electricity provided by GSE[6] from 2009 might be working. Besides, closely examining Table3, the total efficiencies and pure technical efficiencies in Spain and Germany were still efficient within 2009 to 2012, despite the financial support by their governments were terminated or declined before 2008. It implies that the solar electricity markets could operate by the existing market structures and mechanisms in Germany and Spain. As a latecomer, the total efficiency in Taiwan is relatively efficient because the development of solar equipment industries in Taiwan is mature and reaches its mass production technical level rapidly. The reason why solar electricity market in Taiwan could grow rapidly, the gross of solar cell exports reaching over 61 million in 2012 from USD 0.1 million in 2005 of the European market, is that the demand of solar electricity equipment increased significantly from 2004 in the main EU countries.

TABLE 3.RELATIVE EFFICIENCIES AND PEERS FOR 25 SOLAR-ELECTRICITY-DEVELOPMENT COUNTRIES IN EACH YEAR WITHIN 2009 - 2012

Year-country	CRS efficiency	VRS efficiency	Scale efficiency	Peer(s)			
09MEX	0.085	1	0.085	09DNK	09CHE		
09AUT	1	1	1	-			
09BEL	0.448	0.640	0.700	09ESP	09CHE		
09BGR	0.064	1	0.064	09ESP	09CHE		
09CZE	0.204	0.603	0.338	09ESP	09CHE		
09DNK	1	1	1	-			
09FIN	0.766	0.997	0.768	09DNK	09SWE	09CHE	
09FRA	1	1	1	-			
09DEU	1	1	1	-			
09GRC	0.312	1	0.312	09ESP	09CHE		
09ITA	0.344	0.516	0.667	09ESP	09CHE		
09NLD	0.409	0.539	0.758	09DNK	09CHE		
09PRT	1	1	1	-			
09ESP	1	1	1	-			
09SWE	1	1	1	-			
09CHE	1	1	1	-			
09GBR	0.465	0.997	0.466	09DNK	09FRA	09SWE	09CHN
09ISR	0.295	1	0.295	09ESP	09CHE		
09AUS	0.458	0.541	0.846	09DEU	09CHE	09CHN	
09CHN	0.927	1	0.927	09AUT	09DEU		
09IND	0.662	1	0.662	09FRA	09CHN	09JPN	
09JPN	1	1	1	-			
09MYS	0.949	0.952	0.997	09SWE			
09KOR	0.721	1	0.721	09AUT	09DEU	09CHN	
09ROC	0.946	1	0.946	09CHE	09CHN	09JPN	
10MEX	0.093	1	0.093	10DEU	10CHE	10CHN	
10AUT	1	1	1	-			
10BEL	1	1	1	-			
10BGR	0.066	1	0.066	10ESP	10CHE		
10CZE	1	1	1	-			
10DNK	1	1	1	-			
10FIN	0.864	0.997	0.866	10DNK	10SWE		
10FRA	1	1	1	-			
10DEU	1	1	1	-			
10GRC	0.452	1	0.452	10DNK	10ESP	10CHE	
10ITA	0.395	0.589	0.671	10ESP	10CHE		
10NLD	0.412	0.628	0.656	10DNK	10CHE		
10PRT	1	1	1	-			
10ESP	1	1	1	-			
10SWE	1	1	1	-			
10CHE	1	1	1	-			
10GBR	0.466	0.998	0.467	10DNK	10SWE	10CHE	10CHN

[6] GSE is the government-owned company with the mission of promoting renewable energy.

10ISR	0.323	1	0.323	10ESP	10CHE			
10AUS	1	1	1	-				
10CHN	0.933	1	0.933	10AUT	10DEU			
10IND	0.649	1	0.649	10FRA	10CHN	10ROC		
10JPN	1	1	1	-				
10MYS	0.950	0.952	0.998	10SWE				
10KOR	0.872	1	0.872	10DEU	10CHE	10CHN		
10ROC	0.945	1	0.945	10CHE	10CHN	10JPN	10KOR	
11MEX	0.082	1	0.082	11SWE	11CHE	11CHN		
11AUT	0.640	1	0.640	11DEU	11CHE			
11BEL	0.920	1	0.920	11CZE	11GRC	11ITA	11CHE	
11BGR	0.119	1	0.119	11FRA	11ESP	11CHE		
11CZE	1	1	1	-				
11DNK	1	1	1	-				
11FIN	0.933	0.995	0.938	11DNK	11SWE			
11FRA	1	1	1	-				
11DEU	1	1	1	-				
11GRC	1	1	1	-				
11ITA	1	1	1	-				
11NLD	0.375	0.591	0.635	11SWE	11CHE			
11PRT	0.459	1	0.459	11CZE	11ESP	11CHE		
11ESP	1	1	1	-				
11SWE	1	1	1	-				
11CHE	1	1	1	-				
11GBR	0.328	1	0.328	11SWE	11CHE	11CHN		
11ISR	0.335	0.708	0.472	11ESP	11CHE			
11AUS	1	1	1	-				
11CHN	0.930	1	0.930	11DEU	11CHE			
11IND	0.676	1	0.676	11DEU	11CHN	11JPN		
11JPN	1	1	1	-				
11MYS	0.951	0.952	0.998	11SWE				
11KOR	0.902	1	0.902	11DEU	11CHE	11CHN		
11ROC	0.942	1	0.942	11DEU	11CHE	11CHN	11JPN	11KOR
12MEX	0.096	1	0.096	12SWE	12CHE	12CHN		
12AUT	1	1	1	-				
12BEL	1	1	1	-				
12BGR	1	1	1	-				
12CZE	1	1	1	-				
12DNK	1	1	1	-				
12FIN	0.947	0.992	0.955	12SWE	12CHE			
12FRA	1	1	1	-				
12DEU	1	1	1	-				
12GRC	1	1	1	-				
12ITA	1	1	1	-				
12NLD	0.344	0.902	0.382	12SWE	12CHE			
12PRT	0.405	1	0.405	12BEL	12ITA	12CHE		
12ESP	1	1	1	-				
12SWE	1	1	1	-				
12CHE	1	1	1	-				
12GBR	0.321	1	0.321	12DEU	12CHE			
12ISR	0.309	0.682	0.453	12ITA	12CHE			
12AUS	1	1	1	-				
12CHN	0.999	1	0.999	-				
12IND	0.710	1	0.710	12DEU	12CHN	12JPN		
12JPN	1	1	1	-				
12MYS	0.950	0.952	0.998	12FIN	12SWE			
12KOR	0.914	1	0.914	12DEU	12CHE	12CHN		
12ROC	0.942	1	0.942	12DEU	12CHE	12CHN	12JPN	

The government resource managers and policy-makers are interested in estimating how much a particular desirable output can be increased and/or an input can be reduced in terms of improving their energy efficiencies. Additional decreases in specific inputs are needed for solar electricity market to operate as well as the most efficient markets. Increases in desirable outputs could be reached at lower levels of resource inputs. Thus, we then focus on the difference between solar electricity markets within 25 sampled countries. After applying DEA to efficiency evaluation, each inefficient county would be assigned benchmark peer(s) for reference. For example, Taiwan's peers in 2012 are Germany, Switzerland, China, Japan and South Korea, meaning that Taiwan in 2012 can try to emulate these three countries (as far as the proportion of solar electricity is considered) in order to improve the generation of solar electricity that will enable it to be considered best in the DEA study. Therefore, inefficient countries can know the target value of each input and output. Table 4 and 5 report potential improvement of inputs and outputs for total efficiency under CRS and VRS assumption respectively, meaning that inefficient countries can improve efficiency by decreasing resource inputs, undesirable output and/or increasing desirable outputs. For each inefficient country, we break down their inefficiency in terms of specific outputs and inputs, in percentage terms, calculated by "(target value – initial value) divided by initial value" of each input and output. Specifically, Table 4 and 5 accordingly answer the questions: (1) to what extent should governments further decrease their supports while maintaining the electricity utilization at the current level?; and (2) to what extent should governments increase the production of solar electricity generation and decrease the emission of CO_2 air simultaneously?

Referring to table 4 or 5, policy makers can select one of them for improving the performance of inefficient countries based on their preferences. For instance, in terms of the total efficiency under CRS assumption (see table 4), the total expenditure and investment of government, days for getting electricity, total electricity generation and CO_2 emission of 12ROC (Taiwan in 2012) should be reduced by 0.9%, 1.6%, 0.7%, 0.7% and 0.7%, respectively and its proportion of solar electricity should be increased by 20%. After those improvements, 12ROC would become an efficient country among its peer group. In terms of the total efficiencies of all sampled countries, the average potential improvements are total expenditure: -19.8%, gross fixed capital formation: -17.3%, net income per capita: -11.4%, days for getting electricity: -24.3%; GDP: 1.1%, proportion of solar electricity: 7.2%, total electricity generation: -16.8% and CO_2 emissions: -21.7%. Closely examining the average potential improvements, in the future, "days for getting electricity" should be tackled first; in particular, policy makers of countries should pay more attention to the reduction of CO_2 emission during electricity generation.

TABLE 4. POTENTIAL IMPROVEMENT (%) ON TOTAL EFFICIENCY OF INEFFICIENT DMUS DURING 4 YEARS

DMU	EXP	GFCF	INC	DAY	GDP	PRE	TEG	COE
09MEX	-87.1%	-92.6%	-68.5%	-98.8%	4.8%	0.0%	-97.7%	-99.1%
09BEL	-54.4%	-29.3%	-10.8%	-62.7%	0.1%	20.0%	-23.7%	-61.1%
09BGR	-93.5%	-95.3%	-74.7%	-97.9%	0.9%	20.0%	-87.3%	-91.5%
09CZE	-75.2%	-73.6%	-41.2%	-94.4%	0.3%	20.0%	-57.9%	-73.8%
09FIN	-13.0%	-20.9%	-6.7%	-20.6%	0.0%	20.0%	-11.3%	-11.3%
09GRC	-72.6%	-54.3%	-29.9%	-69.0%	0.1%	20.0%	-28.2%	-69.2%
09ITA	-59.2%	-36.5%	-17.8%	-83.5%	0.7%	20.0%	-76.4%	-85.6%
09NLD	-47.7%	-22.0%	-11.3%	-79.5%	0.1%	20.0%	-54.6%	-86.7%
09GBR	-19.3%	-16.3%	-28.0%	-73.0%	0.9%	20.0%	-73.0%	-73.0%
09ISR	-70.5%	-50.1%	-25.7%	-87.7%	0.1%	20.0%	-43.1%	-71.3%
09AUS	-30.4%	-46.3%	-7.1%	-61.2%	0.3%	20.0%	-61.2%	-75.3%
09CHN	-1.2%	-1.7%	-0.2%	-1.8%	2.5%	20.0%	-1.8%	-1.8%
09IND	-23.6%	-23.9%	-13.6%	-21.9%	20.0%	0.0%	-19.5%	-19.5%
09MYS	-0.2%	-0.2%	-0.2%	-0.2%	0.0%	0.0%	-0.2%	-0.3%
09KOR	-4.5%	-23.3%	-15.1%	-22.1%	0.6%	20.0%	-22.1%	-22.1%
09ROC	-1.0%	-1.2%	-0.1%	-0.1%	0.0%	0.0%	-0.1%	-0.1%
10MEX	-88.5%	-90.9%	-66.4%	-96.7%	4.4%	20.0%	-96.7%	-98.4%
10BGR	-93.6%	-93.9%	-75.6%	-97.6%	1.0%	20.0%	-84.7%	-87.5%
10FIN	-6.8%	-8.5%	-1.8%	-7.6%	0.0%	20.0%	0.0%	-7.3%
10GRC	-52.2%	-48.5%	-26.5%	-57.9%	0.0%	0.0%	0.0%	-37.8%
10ITA	-53.0%	-33.0%	-15.5%	-78.5%	0.7%	0.0%	-66.1%	-78.0%
10NLD	-42.3%	-20.7%	-14.4%	-80.5%	0.2%	20.0%	-62.8%	-87.6%
10GBR	-20.1%	-19.0%	-23.4%	-73.2%	0.9%	20.0%	-73.2%	-73.2%
10ISR	-67.6%	-53.4%	-19.9%	-85.3%	0.1%	20.0%	-27.2%	-58.8%
10CHN	-0.9%	-1.3%	-0.1%	-1.4%	2.0%	20.0%	-1.4%	-1.4%
10IND	-24.8%	-25.4%	-13.3%	-23.9%	20.0%	0.0%	-20.9%	-20.9%
10MYS	-0.1%	-0.2%	-0.1%	-0.1%	0.0%	0.0%	-0.1%	-0.2%
10KOR	-2.7%	-8.2%	-4.7%	-6.6%	0.2%	20.0%	-6.6%	-6.6%
10ROC	-1.2%	-1.6%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%
11MEX	-88.6%	-91.8%	-72.2%	-96.9%	4.5%	20.0%	-96.9%	-98.3%
11AUT	-59.8%	-42.6%	-27.3%	-3.1%	0.0%	0.0%	-0.8%	-14.4%
11BEL	0.0%	-5.4%	-5.9%	-2.4%	0.0%	0.0%	0.0%	-17.3%
11BGR	-86.4%	-89.5%	-73.4%	-93.2%	0.5%	0.0%	-41.5%	-41.5%
11FIN	-1.4%	-1.9%	-0.4%	-1.8%	0.0%	20.0%	0.0%	-1.4%
11NLD	-49.5%	-25.5%	-24.0%	-80.2%	0.1%	20.0%	-45.2%	-88.3%
11PRT	-71.3%	-56.5%	-36.7%	-50.0%	0.0%	0.0%	0.0%	-2.3%
11GBR	-60.7%	-31.0%	-35.2%	-80.8%	0.9%	20.0%	-80.8%	-85.9%
11ISR	-66.4%	-57.8%	-29.7%	-83.4%	0.0%	0.0%	-15.3%	-43.1%
11CHN	-1.1%	-1.5%	-0.1%	-1.6%	2.3%	20.0%	-1.6%	-1.6%
11IND	-21.1%	-21.4%	-13.8%	-20.3%	20.0%	20.0%	-19.1%	-19.1%
11MYS	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	0.0%	-0.1%	-0.1%
11KOR	-2.0%	-4.8%	-3.0%	-3.9%	0.1%	20.0%	-3.9%	-3.9%
11ROC	-1.9%	-2.5%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%
12MEX	-85.0%	-91.2%	-69.3%	-95.2%	4.6%	20.0%	-95.2%	-98.3%
12FIN	-0.6%	-0.4%	-0.2%	-0.4%	0.0%	20.0%	0.0%	-0.4%
12NLD	-58.1%	-29.4%	-25.7%	-82.9%	0.1%	20.0%	-49.3%	-89.5%
12PRT	-73.0%	-61.7%	-39.1%	-61.0%	0.0%	0.0%	0.0%	-3.9%
12GBR	-62.0%	-33.5%	-31.0%	-83.4%	0.9%	20.0%	-81.3%	-87.5%
12ISR	-68.4%	-62.8%	-31.0%	-82.8%	0.1%	0.0%	-29.6%	-51.0%
12IND	-17.6%	-17.9%	-11.6%	-17.3%	20.0%	20.0%	-16.4%	-16.4%
12MYS	-0.1%	-0.2%	-0.1%	-0.1%	0.0%	0.0%	-0.1%	-0.2%
12KOR	-1.5%	-3.8%	-2.2%	-3.0%	0.1%	20.0%	-3.0%	-3.0%
12ROC	-0.9%	-1.6%	0.0%	-0.7%	0.0%	20.0%	-0.7%	-0.7%

TABLE 5. POTENTIAL IMPROVEMENT (%) ON PURE TECHNICAL EFFICIENCY OF INEFFICIENT DMUS DURING 4 YEARS

DMU	EXP	GFCF	INC	DAY	GDP	PRE	TEG	COE
09BEL	-26.8%	-0.8%	-3.3%	-44.0%	0.0%	20.0%	-9.1%	-44.0%
09CZE	-6.9%	0.0%	-9.9%	-64.0%	0.2%	20.0%	-40.0%	-54.8%
09ITA	-38.9%	0.0%	-16.2%	-79.2%	0.3%	20.0%	-37.3%	-47.0%
09NLD	-26.5%	0.0%	-2.6%	-69.6%	0.0%	20.0%	-16.2%	-69.3%
09ISR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
09AUS	-17.0%	-32.1%	-6.3%	-56.2%	0.2%	20.0%	-37.6%	-56.3%
10ITA	-10.5%	0.0%	-1.0%	-64.7%	0.6%	20.0%	-56.9%	-64.7%
10NLD	0.0%	0.0%	-6.4%	-66.4%	0.1%	20.0%	-19.4%	-50.7%
11NLD	0.0%	0.0%	-12.6%	-72.7%	0.1%	20.0%	-25.2%	-56.5%
11ISR	-0.6%	-7.5%	-0.9%	-47.0%	0.0%	20.0%	-3.8%	-32.8%
12NLD	0.0%	0.0%	-1.1%	-7.8%	0.0%	20.0%	0.0%	-6.8%
12ISR	0.0%	-6.9%	-0.5%	-48.2%	0.0%	20.0%	-13.2%	-37.7%

Table 6 summarizes the averages of the efficiency scores of countries from 2009 to 2012. This table also calculates the change rates of 2012 in comparison with those of 2009 – 2011. For instance, the change rate of total efficiency with CRS assumption in 2012 in contrast with that of 2009 was 22.83%, implying that the total efficiency in 2012, compared to 2009, was improved by 22.83%. From this finding, we may infer that policy makers made an progress in total efficiency in 2012 compared with 2009 – 2011. Notice that the average is sensitive to outliers. Closely examining Table 3, one may detect that the total efficiency of Israel market in 2012 in contrast with that in 2011 is -0.305, calculated by (VRS of 12ISR) – (VRS of 11ISR). If the outlier is excluded from the computation on average, both of total and pure technical efficiencies would show improvement in 2012 compared to 2011.

Fig. 1 displays the trends of the two efficiency scores over time, indicating the following: (1) although the total efficiency increases significantly from 2009 to 2012, and more slightly increases within the mid-term period 2010 to 2011; and (2) the pure technical efficiency significantly increases from 2009 to 2012, and more slightly increases from 2011 to 2012. The time trends of the two efficiencies are satisfactory for countries during the given period, especially the trend of pure technical efficiency achieves 1.

Fig. 2 shows that averages of total efficiencies and pure technical efficiencies related to developed- and developing-countries. According to this figure, the pure technical efficiency of developing countries is, on average, more efficient than that of developed countries. The reason might be that in recent years, policy makers in developing countries pay more attention on stimulation for solar electricity. For example, in China, the government makes an all-out effort in promoting domestic solar electricity market recent years. Such external factor will influence the fluctuation of pure technical efficiency. However, the total efficiency of developed countries does appear to be significantly efficient than that of developing countries, as expected.

V. CONCLUSIONS

The 25 solar electricity markets operating in sampled countries for solar electricity stimulation may rank the countries as having engaged in protecting environment and improving economy through promoting solar electricity worldwide. Importantly, transforming an economy based on conventional energy into a renewable energy one is an attractive feature of countries, despite the fact that air pollution is an inevitable undesirable by-generation during electricity utilization.

TABLE 6. ANNUAL AVERAGE OF EFFICIENCY SCORE FROM 2009 TO 2012: CHANGE RATE OF 2012 IN COMPARISON WITH THOSE OF 2009 – 2011 IN PARENTHESES.

Efficiency score	2009	2010	2011	2012
Total efficiency	0.682	0.777	0.784	0.838
Change rate	22.83%	7.78%	6.89%	
Pure technical efficiency	0.911	0.964	0.982	0.981
Change rate	7.68%	1.81%	-0.02%	

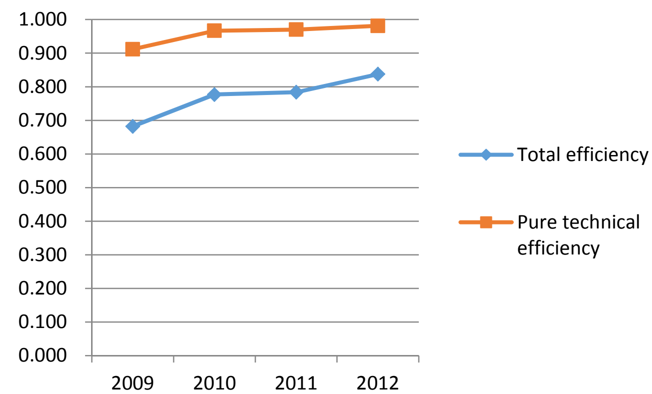

Fig. 1 Time trends of annual average of total efficiency and pure technical efficiency from 2009 to 2012

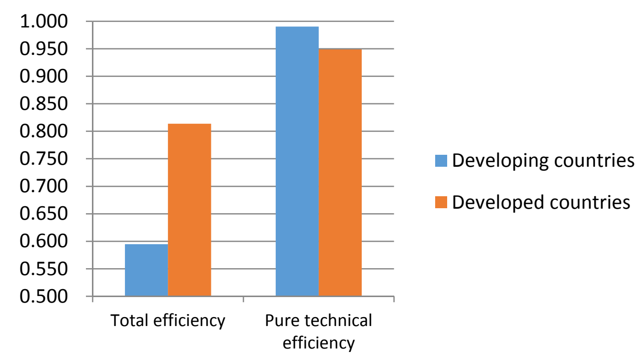

Fig. 2 Averages of total and pure technical efficiencies for developed and developing countries[7]

[7] The classification of countries is referred to the World Bank

This study evaluates the total and pure technical efficiencies of countries with the panel data covering the period of 2009 – 2012. According to the case study results, although the pure technical efficiency of developing countries is, on average, more efficient than that of developed countries, the total efficiency of developed countries does appear to be significantly efficient than that of developing countries.

Finally, after the two efficiencies of solar-development countries are evaluated by using the Non-Separable DEA model, two alternatives for energy, environmental and economic policy making can be made available. One is the expenditure and investment budgeted by governments could focus on encouraging the technology innovation replacing purchasing solar electricity in order to improving solar production efficiency and/or reducing CO_2 emission. The other is based on expected targets of solar electricity proportion and CO_2 emission, governments should to increase the soundness of electricity market in terms of declining their intervention and fiscal supports. Policy makers can select one of these two alternatives for improving the performance of inefficient countries based on their preferences. We hope this study makes a contribution to government for energy, economic and environmental policy making.

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APPENDIX A

COUNTRY AND ITS CODE

Country	Code	Country	Code	Country	Code	Country	Code
Mexico	MEX	France	FRA	Sweden	SWE	Japan	JPN
Austria	AUT	Germany	DEU	Switzerland	CHE	Malaysia	MYS
Belgium	BEL	Greece	GRC	United Kingdom	GBR	South Korea	KOR
Bulgaria	BGR	Italy	ITA	Israel	ISR	Taiwan	ROC
Czech Republic	CZE	Netherlands	NLD	Australia	AUS		
Denmark	DNK	Portugal	PRT	China	CHN		
Finland	FIN	Spain	ESP	India	IND		