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An Exploratory Research for the Development of Strategic Roadmap for Deploying Solar Technology in Developing Countries

Soonwoo Daniel Chang[1], Mun-Su Park[2]

[1]Ph.D. Graduate, Department of Technology & Society at Stony Brook University (SUNY Korea), Korea (sdchang8@gmail.com), First Author
[2]Assistant Professor, Department of Public Policy in College of Health & Welfare at Dankook University, Korea (amhaeng@dankook.ac.kr), Corresponding Author

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ABSTRACT

The solar energy deployment requires cooperation by and among diverse constituents, changes in the national policies, market adoption, and the technologies appropriate for a transformation facilitated towards energy independence. While technological and financial assessments are important, the governing policies and the deployment process play a larger role, as they influence and accelerate penetration and the deployment rate of solar technology. This study introduces a multi-level and interrelated strategic roadmap which provides a perceptual model for the solar deployment. The objective is to enable policymakers to gain insights to the long-term effects of policy elements and realize long-term policy visions. It is intended to provide a holistic approach by connecting the vision with short and long-term goals and assesses different aspects of the time-changing solar technology deployment. Developing a strategic roadmap for policymakers is a novel approach. This study validates the strategic roadmap framework through elicitation of experts. The key finding suggests that six aspects, namely motivation; energy scenario; market and policy assessment; technology and product assessment; dependencies; and barriers are required for a strategic roadmap of policy recommendation.

1. Introduction

Developing countries are aware of the positive influence of renewable energy, as it brings about economic development, the creates new jobs domestically, and provides energy security. While developed countries like Germany are moving rapidly to reach their renewable energy goals, developing countries have just begun their path towards energy independence; leveraging renewable energy resources and solar energy are leading the way. Despite the late start in deploying solar power, developing countries may have more potential than developed countries in achieving their energy independence and leveraging renewable energy resources because of their location, regions with significant sunlight.

Developing countries such as Morocco have set targets to improve their current shares of renewable energy capacity and slowly diminish their reliance on importing energy. Morocco, for example, announced its motivation to achieve transformation towards a renewable energy source (R.E.S.) through 1) internal production and operational capabilities, 2) energy self-reliance, and 3) cost-effective, clean and sustainable energy alternative to the fossil fuels.

There are many factors to consider in deploying a new energy source; technological, socio-environmental, political and even economic issues must be considered. The energy deployment process is multifaceted; thus, different constituents must collaborate to create a smooth transition. The solar energy deployment requires cooperation among diverse constituents, changes in the national policies, market adoption, and the technologies appropriate for a transformation facilitated towards energy independence. While technological and financial assessments are important in the deployment process, policy plays a larger role. Policies accelerate the adoption of solar energy by influencing short-term strategies, long-term visions, and investment decisions in the developing countries where the market is undergoing the inception phase.

Therefore, this research aims to establish a national-level strategic roadmap to deploy solar technology and assist nations in transitioning smoothly to becoming the RES-dependent nations. This study also introduces a multi-leveled and interrelated strategic roadmap framework that will provide the information for the developing countries. This research investigated the appropriate framework for a strategic roadmap of policy recommendation by selecting aspects (layers) and criteria (sub-layers) through the literature review and experts' judgment. A research questionnaire was also carried out with the experts to validate the accuracy of the strategic roadmap.

The rest of the study is organized as follows. Section 2 presents a literature review on the renewable energy potential using solar technology and the importance of roadmap. Then, Sections 3 and 4 present the research framework and the research gaps identified. Finally, Section 5 presents the research method and outcomes, followed by the conclusion of Section 6.

2. Literature Review

2.1 Energy Shortage and the Lack of Energy Infrastructure in the Developing Countries

Data centers, digital platforms, smart phones and Wi-Fi infrastructure are among the essential technologies in today's society. Therefore, the role of energy has become more crucial for the economic development and our daily lives. According to Shahsavarai and Akbari (2018), the global energy demand is set to rise three times by 2050, and the energy demand in the developing countries is due to rapid population growth in Africa and Asia. In addition, Fakih, Ghazalian & Ghazzawi (2020) claimed that the power supply in the developing countries is unreliable and inefficient, and highlighted ineffective policies, high fuel costs, lack of public investment and poor infrastructure as the reasons for the unstable power supply.

The Russo-Ukrainian War has caused the fossil fuel costs to spike. Developing countries, which have preferred fossil fuel as a source of energy due to the lower costs compared to other energy resources, are required to decide as to whether to invest in the renewable energy resources. The Paris Agreement has helped the developed and developing countries increase their interest in the net-zero emissions. According to Papathanasiou (2022), Morocco and India announced their goal to adopt renewable energy as the main source of energy, but the challenges such as technical constraints, inadequate regulatory framework, and weak procurement and planning capacity must be overcome.

2.2 Global Solar and Renewable Energy Potential

Resources are finite in this world. Oil, coal, gas and other natural resources will eventually reach their maximum level of availability and skyrocket in their prices, which is an ongoing issue. The U.S. Department of Energy indicated that “the problems associated with world oil production peaking will not be temporary, and the past experiences of ‘energy crisis’ will provide a relatively little guidance” (Hirsch, Bezdek, & Wendling, 2005).

The energy crisis will affect the society as well as the economy. Finding electricity and power is the main factor in the energy crisis because power is the resource that exploits all other resources. When the energy market falls, an energy crisis will develop. Even today, nations have experienced unexpected power outages or the so-called “blackouts” due to the insufficient energy and high demand for power at a certain point in time. Countries like Bangladesh (Chappell, 2014), Egypt and the United Kingdom (Bacon, 2009) are facing a shortage of energy and continue to fear the “blackouts.” Egypt, for instance, faced its worst energy crisis in decades due to the rising population and increased demand by more than 20% and facing six power cuts per day for two hours at a time (Kingsley, 2014). It led to frustrations and affected both the businesses' production and the citizens' everyday life. However, there have been efforts to mitigate this energy crisis, especially in the energy sector.

In order to avoid very serious social and economic effects, the world needs to emphasize alternate resources to oil, fuel and energy at least ten to twenty years before the peak demand (Hirsch et al., 2005; Sekou, 2014). Similarly, Rees (2014) claimed that to avoid potential problems in the coming years, the “citizens in the industrial countries should be urging their governments to come to an international agreement on a persistent, orderly, predictable, and steepening series of oil and natural gas price hikes over the next two decades.”

The renewable energy industry is gaining popularity among the energy sectors and the nations worldwide for its benefits for the environment, the economy, and our future combined. Renewable energy uses the natural resources that replenish to produce energy. Likewisely, green energy is free of carbon dioxide and other greenhouse gases. There are five primary supplies: sun, wind, water, biomass, and geothermal. It is still a growing industry, and the nations worldwide are aggressively aiming for 100% powered by the renewable energy in the future. However, there are obstacles to transforming the fossil fuel-based energy into the renewable energy.

2.2.1 Challenges for the Solar Technology Deployment

While the past literature has focused on the technical and technological drawbacks (efficiencies and storage), the world faces severe economic and non-economic barriers in deploying the solar technology. Most countries face a lack of capital, support, and even technological infrastructure to succeed in the deployment. Previous studies have examined the barriers and potential problems in deploying solar technologies. According to IEA-RETD (2014), there are three broad areas of challenges such as, 1) whether the system will operate stably without crashing and jeopardizing the security of the energy supply, 2) whether this can be achieved at a reasonable societal cost, and 3) the implementation of such radically different energy architecture and the transition to this from the present one. Table 1 summarizes the other challenges of deploying the solar technologies.

Table 1. Challenges for the Solar Technology Deployment

Challenges	Comments	Source
Social Barriers	Public awareness and the lack of experienced professionals have a moderate influence on the deployment of renewable energy	Moorthy et al., 2019
Economic Barriers	Opportunity cost and opposition by residents influence economic parameters but do not influence the deployment of renewable energy	
Technical Barriers	Lack of infrastructure, operation & maintenance, lack of R&D capabilities, and technology complexity moderately influence the deployment of renewable energy	
Regulatory Barriers	Lack of national policies, inadequate fiscal incentives, and the lack of standards have a significant influence on the deployment of renewable energy	
Legal framework, Financial, Technical, and Public Awareness	Investors’ perspective	Nasirov et al., 2015
Economic	High costs of solar and other EE/RE (energy efficiency and renewable energy) technologies compared with the conventional energy.”	Margolis & Zuboy, 2006
	Inadequate financing options for the EE/RE projects	
	Failure to account for all costs and benefits of energy choices	
Non-economic	Lack of information dissemination and the consumer awareness of conventional energy	
	Difficulty overcoming the established energy systems	
	Identification of the lack of workforce skills, adequate codes and standards, stakeholder participation and poor public perception	
Political	19 documents claimed that there is a lack of government policy support	

Moorthy et al. (2019) examined various barriers to deploying the renewable energy and found that social and technical barriers moderately influence the deployment of renewable energy, and regulatory barriers have a major influence on the deployment, but not the economic barriers. Nasirov et al. (2015) examined the barriers to renewable energy sources (R.E.S.) deployment from an investors' perspective and found legal framework, financial, technical and public awareness as the main barriers. Similarly, Margolis & Zuboy (2006) reviewed 19 documents that addressed solar technology and other renewable energy and identified non-technical barriers. From reviewing the 19 documents, ten barriers were repeatedly shown throughout the documents. For economic barriers, three were identified. Twelve journals have highlighted the importance of the "high cost of solar and other EE/RE (energy efficiency and renewable energy) technologies compared with the conventional energy." Ten have identified "the inadequate financing options for the EE/RE projects," and eight have identified the "failure to account for all costs and benefits of energy choices." For the non-economic barriers, a total of six were identified. Twelve documents have claimed a "lack of information dissemination and consumer awareness with conventional energy." Ten claimed there is a "difficulty overcoming established energy systems," and four to seven journals have identified a lack of workforce skills, adequate codes and standards, stakeholder participation and poor public perception (Margolis & Zuboy, 2006).

There was one more barrier that was most repeated by the 19 documents, which is the lack of government policy support for the renewable energy deployment. Policies are the important sources in deployment as they provide directions over economic, technological, environmental and even social aspects of the deployment. Without clear policies, it would be difficult to subsidize the solar and other renewable energy utilities, the incentives to customers may be insufficient, and there may be difficulty in obtaining the permits for the renewable energy programs and projects.

2.3 Understanding of Roadmapping

According to Kanama, Kondo and Yokoo (2008), a roadmap is useful for the technological foresight because it helps to "visualize technological issues to be solved, products, and markets along a timely axis" and to view the situation as a holistic view. Likewisely, Galvin (2004) defined roadmaps as the tools that "provide an extended look at the future of a chosen field of inquiry drawn from the collective knowledge and imagination of the groups and individuals driving change in that field." Furthermore, Phaal, Farrukh, Mills and Probert (2003) claimed that a roadmap answers the three simple questions of 1) Where are we now?, 2) Where are we going?, and 3) How can we get there?

Roadmaps have become a popular methodology as they can take on various forms and applications. Roadmaps can have different levels and audiences as they can take on various forms and classifications according to their purposes. According to Phaal, Farrukh, and Probert (2001), there are at least eight purposes for creating a roadmap and eight formats a roadmap can have. There are several formats for roadmaps, but the most common approach is proposed by Beeton (2007). The basic framework of a roadmap uses a longitudinal timeframe; the vertical axis is made up of different layers of the roadmap related to the technology. The levels are organized as hierarchical integration of levels; the top level identifies the bigger layer of changing market trends or drivers; the second level examines the product development of the market described in level 1, and the third level identifies the technology R&D of the products in level 2. Finally, a bottom-up method examines the product/technology development and new market opportunities (Beeton, 2007).

Beeton (2007) examined the several studies related to the roadmapping process, ranging from three to nine steps. There are three generic phases (planning, insight collection & processing, and interpretation & implementation). During the planning stage, key elements of the roadmap, such as the constituents or people with experience and knowledge to develop the roadmap, are identified. Insight collection and processing are a data collection stage, as well as updating the initial roadmap framework by communicating with constituents, consulting, and attending workshops. Finally, the interpretation and implementation stage focus on providing information rather than an actual action plan. Knowing that a roadmap is interpreted as the information that may not be represented in the future is important. The audience must understand that roadmaps identify targets and alternative "roads" to meet the vision and needs.

There are several benefits and drawbacks of roadmapping. According to Beeton (2007), communication, collaboration, strategy, and innovation are among the benefits of using a roadmap. Roadmap is a good communicative and collaborative tool because it conveys information in a visual format that can display complex and mass data more comprehensively but also shows the collaborative work of teams and organizations. There are several drawbacks. First, it requires significant time and resources to create one. Second, it requires maintenance and updates regularly, and needs to develop a common vocabulary for a wide range of audiences as there are different types of roadmaps.

2.3.1 Prior Research on the Solar Technology Roadmapping

Beeton (2007) described the roadmapping process and provided a case study of consumer packaging. Phaal (2001b; 2011) summarized the different published roadmaps in various sectors, from general science to policy and government. Over a hundred documents were linked to the energy industry roadmaps across the areas including nuclear, waste, fuel cell, hydrogen energy, coal, clean cities, and renewable energy. In addition, ten documents focused on the solar photovoltaic (P.V.) in the United States, Australia, Japan and Europe.

Much research that created roadmaps focused until 2050 for the global or the European Union perspective. The main factors of the roadmap were mostly economic (levelized cost of electricity (LCOE) and other financial factors such as cost of P.V. modules), technological (efficiency), and environmental (reduction of carbon dioxide (CO_2) level). There has also been researched in the MENA region. Vidican, Böhning, Burger, Regueira, Müller & Wendt (2013), El-Katiri (2014), and International Renewable Energy Agency (IRENA) (2014) assessed or created a roadmap. Problems with such assessments and roadmaps are such that it does not have a clear visualization that can help identify and understand the key goals and barriers of the deployment process. For example, El-Katiri examined barriers but only focused on the environmental and economic factors. The IRENA has created a roadmap that is not easily visualized and conducted a regional SWOT analysis on the MENA region. Table 2 summarizes the various solar technology roadmap studies.

Table 2. Prior Research on the Solar Technology Roadmapping

Type of Research	Focus	Factors	Comment	Source
Roadmap to 2050	Global	Technology & Market development, Policy, Stakeholders, CO2 level	Update of the 2012 version.	IEA, 2014
Roadmap to 2030	Arab States made up of 22 countries	Solar concentrated solar panel, P.V., wind, public competitive bidding, feed-in tariff, net metering, economic, financial and market gaps, technology, human capacity and infrastructure gaps	Used SWOT analysis. Not only solar technologies but other renewable technologies like wind. Had set targets for ten-year intervals.	IRENA, 2014
Assessment and Roadmap without a specific timeline	Morocco	Technological, political, market, business linkages, and industrial development	Set key policy measures in different solar technologies and set whether it was an urgent, short, middle, or long-term priority	Vidican et al., 2013
Roadmap to 2030	MENA	Environmental costs, electricity pricing, economic, regulatory and fiscal incentives	Focused on the whole MENA region, with no short-term goals. Focused on renewable technologies and their applications in the MENA	El-Katiri, 2013

3. Research Framework

This research used the two previous works to create the strategic roadmap framework for solar technology deployment for developing countries. First, it used the sustainable energy roadmap framework created by Ochs (2012), who claimed that the policy recommendation needs to emphasize both the vision (short-term) and long-term goals, specific policy mechanisms and governance & administrative efficiencies assessing factors like energy efficiency, renewable energy potential, grid possibility, LCOE, and international support and cooperation.

Second, this research uses 39 social, technological, economic, environmental, and political (STEEP) decision criteria for the solar technology deployment in Morocco presented by Sheikh (2013). Social perspective consists of job creation, health effects during the production & operations and negative publicity. The technological perspective consists of potential induced degradation (P.I.D.) performance, module energy efficiency, module reliability, module durability, P.V. module design flexibility, power density, state of power plant installation worldwide, state of field performance, the life of P.V. panel and maintenance required. Economic perspective consists of the LCOE, return on investment, total associate inverter and balance-of-system purchase cost, total purchase cost of P.V. modules to utility, warranty/maintenance cost, cost of risk, disposal cost, supply chain maturity, global production supply volume and the use of rare/common materials. Environmental perspective consists of using hazardous materials, greenhouse emissions and pollutants during production, negative ecological footprint, use of available land, water consumption during operations, consumption of other materials during operations, recyclability at end-of-life, waste chemicals at end-of-life and waste gases at end-of-life. Finally, the political perspective consists of governmental incentives, regulatory risks, conformance to existing political, legal, and management constructs, relations with local politics, local sourcing and national priority.

Sheikh (2013) surveyed the relative importance/ranking between the five perspectives of Northwest U.S. Electric Utility worldview. Economic perspectives were ranked the highest, with 26% of the policymakers believing it to be the most important perspective, followed by environmental (22%), technological (20%), social (19%), and lastly, political (12%).

Sheikh, Park & Kocaoglu (2014) conducted similar research on the decision criteria but for the policymakers. The same 39 STEEP criteria were tested, and the authors found that the policymakers ranked economic and environmental factors over social and political factors; however, all five perspectives made material contributions to the solar deployment. The research also compared the value of five commonly used solar P.V.s (c-Si, a-Si, CIGS, CdTe, and organic solar cell) using the STEEP perspective and found that c-Si and a-Si had the highest values for policymakers, followed by the thin-film solar P.V.s. However, some criteria were not possible to extend into a longitudinal study, and hence, some criteria were combined. A total of 29 STEEP criteria were used.

4. Research Gaps

From the literature, two gaps have been identified.

First, much of the prior literature focused on the solar P.V. and roadmapping and has identified economic and technological challenges in the solar technology deployment, such as the LCOE and solar module efficiency. An example of a solar technology roadmap is the IEA (2014) technology roadmap published in 2014. It is an updated version of their original report in 2009 and explores factors affecting the deployment of solar technologies, such as technology & market development, policy, stakeholders, and even carbon dioxide (CO2) emission level till 2050. However, a few studies have explored all of the STEEP perspectives of solar technology deployment in the developing countries.

Second, despite the various technology forecasting and roadmaps on the solar PV technologies, many have focused on the energy prices and technology development. These past roadmaps have a major drawback; they only apply expertise from one technology perspective. It is also impractical to view the changes in the relationships between the criteria of the roadmap. Technology roadmaps are useful for business levels, where one can view the progress and change of the technology, but they will not apply to the policymakers and state agencies. In order to be a useful tool to nations, a new type of strategic roadmap that focuses on the different aspects of the industry situation is needed.

To address such gaps, this paper conducted an exploratory study to introduce a multi-level and interrelated strategic roadmap to provide a perceptual model for solar deployment. The objective is to enable the policymakers to gain insights to the long-term effects of the policy elements and how policy visions may be realized. It provides a holistic approach by connecting the vision and long-term and short-term goals and assessing the different aspects of the time-changing solar technology deployment. Developing a strategic roadmap for policymaking is a novel approach.

5. Methods and Outcomes

5.1 Stage 1 – Building the Strategic Roadmap Framework

This strategic roadmap is “a perceptual model which provides short-term strategies and long-term visions to help assess motivations and STEEP (social, technological, economic, environmental, and political) perspectives of policies and technologies at the national level.” According to Phaal and Muller (2009), a roadmap should be carefully and thoughtfully planned and designed with appropriate timelines, layers and criteria. Since roadmaps are concerned with future goals and vision, the study decided to implement short-term goals every five years and a long-term vision for twenty years from now. In addition, the study focused on six layers (motivation of deploying solar technology, energy scenario, market and policy assessment, technology and product assessment, dependencies and barriers). Table 3 shows the initial 60 criteria and six layers of the STEEP roadmap.

Table 3. Initial Six Layers and 60 Criteria of the STEEP Roadmap

Motivation for Deploying Solar Tech.	Energy Scenario	Market and Policy Assessment	Technology and Product Assessment	Dependencies	Barriers
Regional Scenario	Global Annual Solar Power Capacity	Social: 3 Criteria	R&D Focus at Technology and Component Level	Development of Smart Grids	Cos Barriers related to P.V. Deployment
National Scenario	Global Cumulative Solar Power Capacity	Technological: 6 Criteria	R&D Focus at a Systematic Level	Development of Domestic Market	Investment Barriers related to P.V. Deployment
Rural Scenario	Global Solar Power Share (% of Solar Over Total Power Capacity)	Economic: 8 Criteria	R&D Focus for Region Area		Other Potential Barriers
Urban Scenario	Cumulative Solar Power Capacity	Environmental: 5 Criteria	R&D Focus for Rural Area		
	Solar Power Share	Political: 7 Criteria	R&D Focus for Urban Area		
	Renewable Energy Electricity (REN) Target		P.V. Modules Focus		
			Global Focus for P.V. modules		

5.2 Stage 2 – Validation Process

5.2.1 Structuring the Research Questionnaire

A research questionnaire was developed based on the strategic roadmap with Microsoft Word Documents. The research questionnaire contained 14 “Yes or No” questions (check the box if valid and relevant) in two parts. The first part of the research questionnaire validated the appropriability and practicability of the six aspects selected in the strategic roadmap. The second part of the research questionnaire was used to validate the reliability of the elements for current and vision situations for the market and policy assessment aspect of the strategic roadmap.

5.2.2 Experts Selection and Concuting the Questionnaire

Experts are the individuals with working experiences and knowledge in the specific areas of their expertise, and their judgments and opinions can be used in multiple ways. For example, they can be used to provide insights and forecast future events, as well as determine valid information. According to Meyer and Booker (2001), the expert judgment elicitation process consists of structuring a research questionnaire, selecting and motivating experts, selecting and designing building blocks of elicitation to fit target applications, elicitation practice with pseudo-experts, and finally, elicitation with experts.

The ideal number of experts in each research is six to twelve per field of expertise. According to Knol, Slottje, Van der Sluijs & Lebret (2010), the marginal effect of adding more after twelve more experts does not have a significant impact on the research. Several elicitation methods exist, such as face-to-face interviews and web-based communication, such as emails or other applications. It ranges from snowball sampling, which is a common method where experts name a few more experts, to use databases or associations to find ways to contact experts.

This study used the Google's advanced searches for "solar policymakers," "solar technology," and "solar roadmaps", then used the snowball sampling method for recommendations. A total of 60 invitations were sent out to ask for their participation in the research questionnaire and received 21 replies. However, after reviewing the research questionnaire, some experts decided not to participate since it was not within the realm of their expertise, while others did not reply. So a total number of eight experts were gathered. Most of the experts were knowledgeable in solar technology and related policies, with a wide range of working and research experience from five years to over 20 years.

5.2.3 Analyzing the Results

The elements were validated by consensus; part one had seven people complete the research questionnaire, while in part two, five people completed it. Therefore, in part one, if more than four experts (more than half of the experts) agreed upon an aspect, it was selected for and in the strategic roadmap framework. Similarly, the elements were validated. Unlike part one of the research questionnaire, five experts fully completed and answered all the questions in part two. Therefore, the threshold for this Section was the consensus of the three experts' judgment in order for it to be valid. Eight elements were invalid (present situation for P.I.D. performance, power plant & field performance, use of hazardous materials, available land, water consumption and location politician, and visions for LCOE and available land). The individual elements of each criterion are presented in the Analysis of the Results Section.

5.3 Validated STEEP Roadmap for the Solar Technology Deployment in the Developing Countries

The initial strategic roadmap was examined through the research questionnaire and the experts' judgments. Table 4 shows the overall strategic roadmap framework. A final six aspects (motivation, energy scenario, market and policy assessment, technology and product assessment, dependencies, and barriers) were selected, and 45 criteria (3 for Motivation, 4 for Energy Scenario, 28 for Market and Policy Assessment, 5 for Technology and Product Assessment, 2 for Dependencies, and 3 for Barriers) were chosen.

Table 4. Initial Six Layers and 60 Criteria of the STEEP Roadmap

Solar PV Deployment for Developing Countries				Past	Current	+5	+10	+15	Vision (+20)
Motivations for Deploying Solar Tech.	National Scenario								
	Rural Scenario								
	Urban Scenario								
Energy Scenario	Global Annual Solar Power Capacity								
	Global Solar Power Share (% of solar over total power capacity)								
	Cumulative Solar Power Capacity								
	Solar Power Share								
Market & Policy Assessment	Social	Job Creation							
		Health Effects- During Production and Operations							
	Technological	Potential Induced Degradation (PID) Performance							
		Module Energy Efficiency & Power Density							
		Module Reliability & Durability							
		State of Power Plant Installation Worldwide & Field Performance							
		Life of PV Panel (Degradation) & Maintenance Required							
	Economic	Levelized Cost of Electricity (LCOE) ($/kWh)							
		Return on Investment ((Net profit / Investment) × 100)							
		Total Associate Inverter and Balance-of-System Purchase Cost & Purchase Cost of PV Panels to Utility							
		Warranty/Maintenance (Operational)							
		Disposal Cost							
		Cost of Risk							
	Environmental	Use of Hazardous Materials							
		Use of Available Land							
		Consumption of Water During Operations							
		Waste Chemicals at End-of-Life							
	Political	Government Incentives & Regulatory Risk							
		Conformance to Existing Political Legal, Management Constructs by Utilities							
		Local Sourcing							
		Relations with Local Politicians							
		National Priority	Energy Self-Reliance						
			Clean/Cost-Effective Energy						
			Internal Production/ Operational Capabilities						
Technology/ Product Assessment	PV System R&D Focus	Global	Component Level						
			System Level						
		Rural Area							
		Urban Area							
	PV Types & Generations	Regional							
		Global							
Dependencies	Development & Evolution of other Resources	Grid Connection							
		Domestic Market Creation and Maturation							
Barriers	Cost								
	Subsidies and Investment								
	Others								

6. Conclusion

This paper has made several contributions to the solar deployment process for the developing countries. First, it introduced a strategic roadmap framework created through the literature reviews and validated by experts in the solar policymaking and solar technology through a research questionnaire. Second, the paper provides a solution to visualize solar technology deployment holistically across all social, technological, economic, environmental, and political perspectives. For the developing countries to further enhance their energy security, they must strengthen their policies and set short- and long-term goals. Therefore, this paper provides a solution which the developing countries can use to create a clear-cut strategy to achieve their energy objectives.

There are several limitations to the study. First, while this is a strategic roadmap for the policy recommendation, it does not indicate or recommend policies to accelerate or facilitate the transition from the energy importing to the energy self-reliant nation. Instead, this strategic roadmap provides an overall approach to the deployment process by laying out steps and a holistic strategy visually. Second, the elements for the strategic roadmap were based on the secondary data from governmental agencies and the energy industry. Third, the number of experts used to validate and analyze the questionnaire results must be carried out even more systematically in the future studies. Despite the limitations, the research provides the meaningful information as it provides a visualization to help examine and understand the deployment processes and intermediate steps to holistically reach the final goal of being energy self-reliant. In addition, this methodology is novel in that it enables the policymakers to gain their insights to the long-term effects of the policy elements and how policy visions may be realized.

Conflict of Interest Statement

The authors declare that: (i) no support, financial or otherwise, has been received from any organization that may have an interest in the submitted work; and (ii) there are no other relationships or activities that could appear to have influenced the submitted work.

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