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Breaking barriers in deployment of renewable energy

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Abstract

Several economic, institutional, technical and socio-cultural barriers hinder countries from moving from the high to the low emission pathway. The objective of this research is to find out the impacts of social, economic, technological and regulatory barriers in the deployment of renewable energy. Data were collected through an online questionnaire responded to by 223 professionals working in the energy sector all over the globe. This research shows that social, technological and regulatory barriers have a strong influence on the deployment of renewable energy, while economic barriers significantly influence it indirectly. By breaking research and development-related barriers, organizations will be able to invest greatly in developing advanced technologies that can optimize usage of renewable energy and make renewable energy appear more lucrative. With less polluting and lower tariff energy solutions being made available to local people, and higher profits for manufacturers, this will create an atmosphere where all stakeholders are satisfied.

Keyword: Business

1. Introduction

The world's population is growing at an unprecedented rate and that has necessitated a dramatic increase in energy demand globally. Matching supply with this surging demand is a principal and critical challenge for countries around the world. Currently, this demand is being met through the increased use of fossil fuels. The majority of the world's power is generated from the use of coal, oil and gas. These so-called fossil fuels, when burned, release heat energy which is then converted into electricity releasing into the atmosphere a lot of carbon dioxide (CO_2), a greenhouse gas that contributes to the issue of global warming. A renewable energy supply offers a solution to both challenges. For economic growth and human advancement, energy has always been universally considered one of the most crucial measures (Rawat and Sauni, 2015). There is a three-dimensional relationship alongside a bi-directional causal relationship between economy, the environment and energy (Azad et al., 2014).

Globally, the population is growing at fast rate; however, the world's energy demand is likely to grow even more rapidly than the increase in the population. According to International Energy Outlook (2013), global energy demand will be increased by 56 per cent between 2010 and 2040 (Azad et al., 2014). Currently, the majority of the world's energy consumption is satisfied by consuming energy created using fossil fuels. To satisfy the ever-increasing energy demand and to protect the climate, breakthrough advancements have been made in the past to design technologies that can control and harness power from alternative energy sources. As controlling carbon emissions is critical in dealing with climate change, renewable energy is an appropriate way to satisfy energy demand without degrading the ecosystem (Jing, 2016). Apart from bringing environmental sustainability, renewable energy offers another advantage—the ability to provide power to even the most underprivileged people living in the remotest areas where traditional power is not yet available (Rawat and Sauni, 2015).

Awareness of the need to encourage deployment of renewable energy has increased drastically in recent years. More countries, whether developed or developing, are promoting and changing policies to promote the deployment of renewable energy. In 2005, only 55 countries had taken steps to make renewable targets and create policies supporting renewable energy. This number had increased to 144 countries by 2013, with almost all the world understanding the need to reduce carbon emissions.

2. Background

Despite remarkable promotion and commitment from various nations, only a small percentage of energy is generated from renewable energy, especially in developing countries. This scenario is because of the numerous barriers that control the diffusion

of renewable energy. These barriers prevent renewable energy from effectively competing with traditional energy and hamper achievement of the necessary large-scale deployment (Nasirov et al., 2015). Penetration and scale-up of renewable require a strong political and regulatory framework which supports and promotes a continued focus on fossil fuels (Karatayev et al., 2016).

A review of the literature shows that many studies have been conducted to identify barriers to the use of renewable energy. However, very few studies have grouped these barriers and discussed the impact of these barriers in the deployment of renewable energy. The variables which were identified from the literature review for use in future research were *social barriers*, *economic barriers, technological barriers and regulatory barriers*.

The objective of this research is to discover the impacts of breaking barriers in the deployment of renewable energy. This research tries to resolve the following questions to reach a solution which is in line with the objective of this research:

a. What are the factors affecting the deployment of renewable energy and are they significant or not?

b. What impact will breaking barriers have on the deployment of renewable energy?

c. In the wake of breaking barriers, is Rogers' (2003) theory of diffusion (political and social) valid for renewable energy?

3. Theory

Theory of diffusion (technical, political & social) in the wake of breaking barriers.

Diffusion of innovation theory is one of the most important concepts in theorizing the changing format of energy provision, being concerned with the process of adoption of innovations by society (Lacerda et al., 2014). Rogers (1983: 11) defined diffusion as 'the process by which innovation is communicated through certain channels over time among members of a social system' and innovation as 'an idea, practice or object that is perceived as new by an individual or other unit of adoption' (Sahin, 2006). Other types of diffusion include social diffusion and theories of change, going back to Lewin's description of the need to alter group standards to promote lasting individual change (Lewin, 1951). The focus has since shifted towards external conditions that are likely to be more influential than group decisions (Darnton, 2008). Political diffusion deals with the spread of policies and governance approaches across jurisdictional boundaries which come about because of external pressures and/or internal pressures relating to quests for legitimacy (Weyland, 2005). More fundamentally, diffusion defines the often random movement of a

characteristic. The theory of diffusion is used to understand the attitude and perception of people with regard to government policies.

4. Hypotheses

This literature review looks at the outcomes of penetration and deployment of renewable energy, which are affected by four major factors: social barriers, economic barriers, technological barriers and regulatory barriers.

4.1. Social barriers

The transition from conventional resources to renewable energy has encountered public resistance and opposition. This is due to a lack of awareness of the benefits of renewable energy, disruption of seascape, and acquisition of land which could have been used for agriculture, tourism, etc. (Goldsmiths, 2015).

Public awareness and information barriers: Sustainable development stems from the satisfaction of human desires, through socially recognized technological systems and suitable policies and regulatory tools (Paravantis et al., 2014). The main concerns with respect to public understanding are: 1) insufficient information regarding ecological and financial benefits; 2) inadequate awareness of renewable energy technologies (RET); and 3) uncertainties about the financial feasibility of RE installation projects (Nasirov et al., 2015).

Not in my backyard' (NIMBY) syndrome: According to NIMBY syndrome, people do support renewable energy generally, but not in their own neighbourhood. Renewable power project proposals often face opposition from individual citizens, political leaders, grassroots organizations, national interest groups and, in some cases, even environmental groups (Jianjun and Chen, 2014). Public opposition occurs for a number of reasons, including landscape impact, environmental degradation and lack of consultation concerns among local communities (Nasirov et al., 2015).

Loss of other/alternative income: A major issue with renewable plants (especially solar and wind farms) is the vast area of land required to produce an amount of energy equivalent to that which can be produced from a small coal fire power plant (Chauhan and Saini, 2015).

To make a significant contribution to global energy consumption, there is a need to develop large scale renewable energy plants, but this requires vast areas of countryside. Enormous parts of the countryside, which includes farmland, need to be converted into buildings or roads or any other infrastructure to support a renewable energy power plant. In achieving this, often agriculture, tourism, fishing, etc. can be affected (Nesamalar et al., 2017).

Lack of experienced professionals: Universal transition from fossil fuels to renewable energy sources requires the solid foundation of a skilled labour force. There is huge demand for skilled professionals to design, build, operate and maintain a renewable energy plant.

Incompetent technical professionals and lack of training institutes prevent renewable energy technologies from scaling new heights (Ansari et al., 2016). There is a need to teach renewable energy courses and for proper training to be conducted to develop the skills required to install and operate renewable energy projects. The shortage of trained workforce to design, finance, build, operate and maintain renewable energy projects is considered a major obstacle to the wide penetration of renewable energy (Karakaya and Sriwannawit, 2015).

H1: Social barriers have a significant influence on the deployment of renewable energy.

H2: Social barriers have a significant influence on economic barriers.

4.2. Economic barriers

Factors influencing economic and financial barriers are high initial capital, lack of financial institutes, lack of investors, competition from fossil fuels, and fewer subsidies compared to traditional fuel (Raza et al., 2015). These factors have prevented renewable energy from becoming widespread.

Tough competition from fossil fuel: Fossil fuels will remain a dominant player in supplying energy in the future. A report by EIA's International Energy Outlook (2016) suggests that fossil fuels (oil, natural gas and coal) are expected to supply 78 per cent of the global energy used in 2040. Investment in fossil fuels (including supply and power generation) still accounts for 55 per cent of 2016 global energy investment, compared with 16 per cent for renewable energy. Coal is still a dominant fuel source in most counties because of its abundance, which makes it cheap and accessible (Dulal et al., 2013). There have been huge changes in energy since summer 2014. Oil, as measured by the Brent crude contract, which was priced at \$115.71/barrel in June 2014, fell to \$27.10 on 20 January 2016, a huge drop of 76 per cent. Similarly, the ARA coal contract dropped from \$84/tonne in April 2014 to \$36.30 in February 2016. There was a huge decline in the price of natural gas, which slid from around \$4.50/MMBtu in June 2014 to \$1.91 in mid-February 2016. Due to falling prices and fossil fuel still emerging as a cheaper alternative to renewable energy, it is able to offer tough competition to renewable energy projects.

Government grants and subsidies: The amount of government subsidies provided to conventional energy is much higher than the subsidies awarded to renewable energy.

This keeps renewable energy at a disadvantage. The subsidies provided by governments to generate electricity from fossil fuel sources is overshadowing the wide use of low emission technologies. For example, coal companies in Australia and Indonesia still receive government subsidies for mining and exploration (Dulal et al., 2013).

Fewer financing institutions: Renewable energy developers and producers face severe difficulties in securing financing for projects at rates which are as low as are made available for fossil fuel energy projects (Ansari et al., 2016). There are limited financial instruments and organizations for renewable project financing. This reflects that the investments are considered somewhat risky, thus demotivating investors (Ohunakin et al., 2014).

High initial capital cost: Renewable energy projects require high initial capital cost and, because of the lower efficiency of renewable technology, the net pay back period is high, which in turn pushes investors on to the back foot (Ansari et al., 2016). Both the users and the manufacturers may have very low capital and to install a plant they require capital financing. This problem is further highlighted by the strict lending measures that restrict access to financing even when funding is available for traditional energy projects (Suzuki, 2013). High cost of capital, often lack of capital and most important with high payback period projects often becomes un-viable (Painuly. J, 2001).

Intangible costs: Currently, in almost all countries, the total cost of fuel includes the cost of exploration, production, distribution and usage, but it does not include the cost of the damage it does to the environment and society. Despite severe effects on health and on the atmosphere, the unseen costs (externalities) which are connected with traditional fuels are not included in their price (Arnold, 2015). Understanding these impacts is essential for evaluating the actual cost of utilizing fossil fuels for energy generation.

H3: Economic barriers have a significant influence on the deployment of renewable energy.

4.3. Technological barriers

There are a number of legitimate technological barriers to the widespread deployment of renewable energy, including limited availability of infrastructure, inefficient knowledge of operations and maintenance, insufficient research and development initiatives, and technical complexities like energy storage and unavailability of standards (Zhao et al., 2016).

Limited availability of infrastructure and facilities: There is limited availability of advanced technologies required for renewable energy, especially in developing

countries, which acts as a factor preventing penetration of renewable energy. Even if this technology is available, the cost of procuring it is very high (Dulal et al., 2013). Since renewable energy power plants are mostly placed in remote locations, they require additional transmission lines to connect to the main grid. Since most of the existing grids are not designed to integrate with renewable energy, these existing grids need to be upgraded or modified (Izadbakhsh et al., 2015). Grid integration is amongst the biggest problems affecting the development of renewable energy projects.

Lack of operation and maintenance culture: Since renewable energy technology is comparatively new and not optimally developed, there is a lack of knowledge about operation and maintenance. Efficiency cannot be achieved if a plant is not optimally operated and if maintenance is not carried out regularly (Sen and Bhattacharyya, 2014). Lack of availability of equipment, components and spare parts will require a substantial increase in the production costs, as these items need to be imported from other countries, therefore being procured at high prices and so increasing the overall cost (Bhandari et al., 2015).

Lack of research and development (R&D) capabilities: Investment in research and development (R&D) is insufficient to make renewable energies commercially competitive with fossil fuel. Both governments and energy firms shy away from spending on R&D as renewable energy is in its development stage and risks related to this technology are high (Cho et al., 2013).

Technology complexities: There are not enough standards, procedures and guidelines in renewable energy technologies in terms of durability, reliability, performance, etc. This prevents renewable energy from achieving large scale commercialization (Nasirov et al., 2015). A major technical issue which renewable energy is facing today is the storage of energy. The supply of sun or wind is not continuous despite their infinite abundance and electricity grids cannot operate unless they are able to balance supply and demand. To resolve these issue, large batteries need to be developed which can compensate for the times when a renewable resource is not available (Weitemeyer et al., 2014).

H4: Technological barriers have a significant influence on the deployment of renewable energy.

H5: Technological barriers have a significant influence on economic barriers.

4.4. Regulatory barriers

Factors like lack of national policies, bureaucratic and administrative hurdles, inadequate incentives, impractical government targets, and lack of standards and

certifications have prevented renewable energy from expanding dramatically (Stokes, 2013).

Ineffective policies by government: Strong regulatory policies within the energy industry are not only required for a nation's sustainable development, but also resolve the inconsistency between renewable and non-renewable energy. Lack of effective policies creates confusion among various departments over the implementation of the subsidies. Major issues such as unstable energy policy, insufficient confidence in RET, absence of policies to integrate RET with the global market and inadequately equipped governmental agencies act as barriers to the deployment of renewable energy projects (Zhang et al., 2014).

Inadequate fiscal incentives: There have not been enough measures by governments to remove tax on imports of the equipment and parts required for renewable energy plants. Feed-in tariffs are the measures by which governments aim to subsidize renewable energy sources to make them cost-competitive with fossil fuel-based technologies, but the absence of these adequate financial incentives results in high costs that hinder the industry's development, operation and maintenance, and stagnate the future (Sun and Nie, 2015).

Administrative and bureaucratic complexities: Obstacles arising in the deployment of renewable energy projects are manifold, including (and not limited to) administrative hurdles such as planning delays and restrictions. Lack of coordination between different authorities and long lead times in obtaining authorization unnecessarily increase the timeline for the development phase of the project. Higher costs are also associated with obtaining permission due to lobbying. All these factors prolong the project start-up period and reduce the motivation required to invest in renewable energy (Ahlborg & Hammar, 2014).

Impractical government commitments: There is a gap between the policy targets set by governments and the actual results executed by implementation (Goldsmiths, 2015). There is a lack of understanding of a realistic target and loopholes in the implementation process itself. The responsibility for overcoming these commitment issues lies with governments. Policies should be devised that can offer clear insight into important legislation and regulatory issues so that the industry can be promoted as stable and offering growth. Governments can fix this mismatch by becoming more responsive and reactive.

Lack of standards and certifications: Standards and certificates are required to ensure that the equipment and parts manufactured or procured from overseas are in alignment with the standards of the importing company. These certifications make sure that companies are operating the plant in compliance with local law. Absence of such standards creates confusion and energy producers have to face unnecessary difficulties (Emodi et al., 2014).

H6: Regulatory barriers have a significant influence on the deployment of renewable energy.

H7: Regulatory barriers have a significant influence on economic barriers.

4.5. Breaking barriers in deployment of renewable energy

Deployment of renewable energy is crucial not only to meet energy demands but also to address concerns about climate change (Byrnes et al., 2013). However, the barriers (social, economic, technological and regulatory) existing in this sector prevents the development and penetration of renewable energy globally.

User-friendly procedures: Bureaucratic procedures in the deployment of renewable energy are considered the biggest hindrance, and this demotivates investors and entrepreneurs from entering and investing in renewable energy. Government policies are not aligned at national and state level, thus failing to attract energy sector investment (Nesamalar et al., 2017). Countries with excessively complicated administrative procedures have less penetration of renewable energy compared to countries with simple and straightforward procedures (Huang et al., 2013).

Higher stakeholder satisfaction: Energy is the backbone of the socioeconomic development of any country (Raza et al., 2015). By utilizing more renewable energy resources, nations can help fulfil energy deficiencies without damaging nature. The repercussions of this change would be the creation of more jobs in the designing, building, operation and maintenance of renewable energy project infrastructures. Higher levels of diffusion will help to achieve economies of scale, and that will bring down the costs and thus the price for the end user. This will improve investors' confidence and will trigger increased investments in renewable energy projects. Higher benefits can be reaped from the availability of green energy as there will not be severe environmental implications, and that can help in maintaining the earth's ecosystem.

Successful research and development (R&D) ventures: In a study conducted by Halabi et al. (2015), it was pointed out that technological advancement to effectively generate, store and distribute renewable energy at lower costs is crucial. However, compared to conventional energy, insufficient R&D initiatives are undertaken. This is due to fact that organizations are unable to earn beneficial returns from R&D, and that makes the future of these initiatives look dull.

Cost savings: The biggest challenge that renewable energy faces is the competition from low cost fossil fuels (El-katiri, 2014). Renewable energy projects require huge land areas to produce the amount of energy which a conventional plant can produce in a small area. Prohibitive costs are involved in establishing and running renewable energy projects, mainly due to the huge financial capital required to acquire a

suitable piece of land, the costs associated with lobbying, and power losses due to inefficient energy storage capabilities.

5. Methodology

The research framework of this study is given in Fig. 1 below:

5.1. Data collection

The survey questionnaire (please see the questionnaire) was framed based on independent variables and their sub-variables. The questionnaire, a pretesting of the questionnaire was conducted to ensure that all the questions were relevant and understandable to respondents. Initially, the survey questionnaire was sent out to 33 energy industry experts and their feedbacks were collected. The insights generated from this pilot testing led to further refinement of the questionnaire and a final questionnaire was developed. The final survey form consisted of 26 main questions for both dependent and independent variables and another three questions to understand the demographics of the respondent. Each question consisted of five options (Likert scale) from which the respondent had to select the one which he/she thought suited the best, with '1' as strongly disagree and '5' as strongly agree.
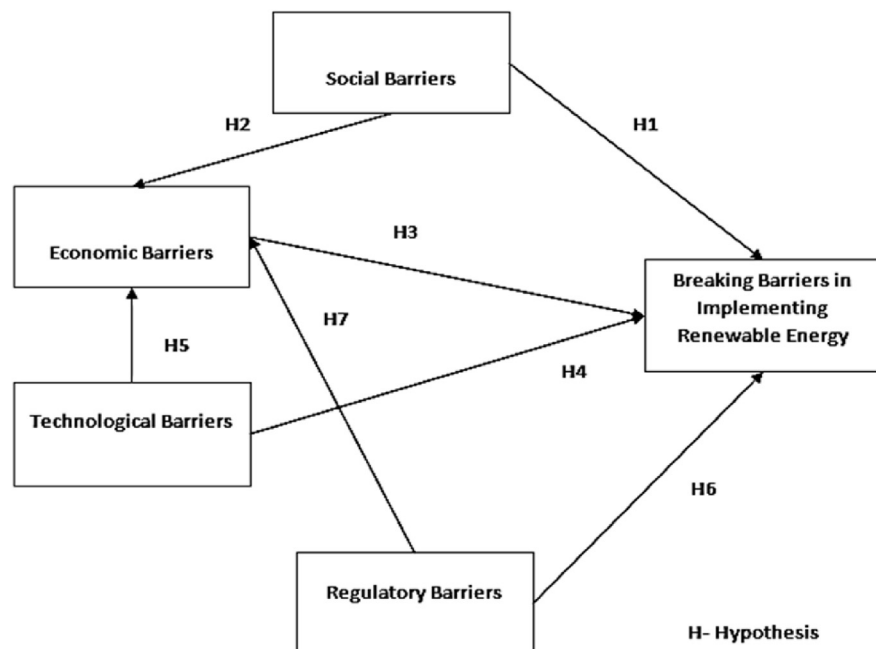

Fig. 1. Research framework.

5.2. Profile of respondents

The survey respondents were professionals in the energy industry (manufacturing of rigs, power generation, power distribution, oil and gas, mining and renewable energy). The participants were selected based on their familiarity with and knowledge of renewable energy sources and technology across America, Europe, Asia Pacific, Africa and Australia. The survey questionnaire was sent out to 645 potential respondents, of which only 223 practical survey responses were received. The response rate is calculated to be 34.5 per cent. The demographics of the respondents are provided in Table 1.

5.3. Data analysis

The data collected from the survey questionnaire were analysed using ADANCO 2.0.1 software. ADANCO software is used for this purpose as it is specialised for variance based structural equation modelling. It implements several limited information estimators such as partial least squares path modelling or ordinary least squares regression based on sum scores for testing the hypothesis and analysing research models (Henseler et al., 2014). To verify the correlation and confidence in the hypotheses, ADANCO software works well as it does not enforce normality on the data. Data analysis was conducted by first gauging the modelling of the structural model and then measuring the reliability and validity of the model by estimating model parameters.

5.4. Reliability

Cronbach's alpha value was considered to determine the reliability of the model fit. Alpha values above 0.7 show a satisfactory level of reliability. Jöreskog's Rho value

Table 1. Demographics of the respondents (n = 223) with respect to job level, region and industry sector across energy sector.

Item	Measure	Frequency	Percentage
Job level	Senior level executive	76	34
	Middle level executive	110	49.3
	Junior level executive	37	16.7
Region	Asia Pacific	164	73
	Europe	22	9.8
	Middle East & Africa	12	5.9
	North & South America	14	6.3
	Australia	11	5
Industry type	Power generation	22	9.85
	Power distribution	44	20
	Manufacturing of oil rigs	69	30.55
	Oil and gas	58	26.4
	Mining	15	6.6
	Renewable energy	15	6.6

also confirms that the model is consistent and uniform: i.e. composite reliability is within the appropriate range (Marshall, 2014). The figures for each construct are listed in Table 3.

5.5. Convergent validity

Convergent validity can be defined as the degree to which two measures of constructs that theoretically should be related are in fact related (Campbell and Fiske, 1959). The value of average variance extracted is required to be above 0.5 in order to be accepted. The convergent validity is shown in Table 2 below. The minimum AVE value obtained is 0.5042, which proves that the validity of this model is acceptable.

5.6. Discriminant validity

Discriminant validity is used to test if the models or concepts that are not in relation are unrelated. According to Fornell and Larcker's theory (Cable et al., 2014), if the root of the average variance extracted (AVE) of one path is less than the average variance extracted (AVE) of the other path, then it is considered accepted. In Table 3 below, Fornell and Larcker's theory is successfully matched; thus the discriminant validity of this model is satisfactory.

5.7. Structural equation model (SEM)

Structural modelling through bootstrapping is provided in Fig. 2. Path analysis is a special case of structural equation modelling and employs a causal modelling approach to explore the correlations within a defined network. This correlation is equated by calculating the sum of the contributions of the paths that connect all the variables. To evaluate the strength of each path, products of the path coefficients along the path are calculated (Schreiber et al., 2015). The R-squared value of our research model is 0.545, which supports the research model.

Table 2. Overall Reliability of the construct and Convergent validity.

Construct	R^2	Jöreskog's rho (ρ_c)	Cronbach's alpha (α)	Average variance extracted (AVE)
Breaking barriers in implementation of RE	0.545	0.8924	0.8391	0.6749
Social barriers		0.8953	0.8536	0.5971
Economic barriers		0.8778	0.7918	0.5042
Technological barriers		0.8617	0.7941	0.6588
Regulatory barriers		0.928	0.9065	0.5558

Table 3. Discriminant validity: Fornell-Larcker criteria.

Construct	Breaking barriers	Social barriers	Economic barriers	Technological barriers	Regulatory barriers
Breaking barriers	0.6749				
Social barriers	0.2498	0.5971			
Economic barriers	0.3066	0.4171	0.5042		
Technological barriers	0.3674	0.4197	0.4529	0.6588	
Regulatory barriers	0.5207	0.2917	0.4413	0.5052	0.5558

5.8. Hypothesis testing

ADANCO 2.0.1 is used to conduct hypothesis testing because it uses variance to model structural equations. The bootstrapping option can be selected in the ADANCO software to model unknown population data (Sarstedt et al., 2011). The level of significance is measured by establishing the t-statistic. The outcomes of the hypothesis testing is given in Table 4 below:

6. Results

In total, seven hypotheses were identified. Out of the seven hypotheses, six hypotheses are accepted as their path coefficient is either positively or significantly related. A detailed explanation of each hypothesis is given below.
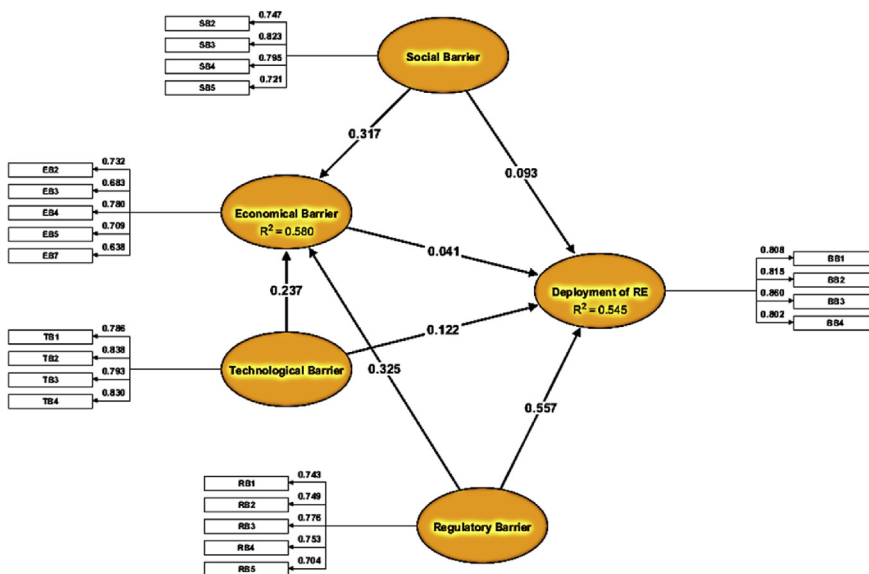

Fig. 2. Structural modelling through bootstrapping.

Table 4. Outcomes of the hypothesis testing.

Hypotheses	Effect	Original coefficient	Standard bootstrap results						
			Mean value	Standard error	t-value	p-value (2-sided)	p-value (1-sided)	Accepted
H1	SB ->RE	0.1063	0.1145	0.0567	1.8749	0.0611	0.0306	Yes
H2	SB -> EB	0.317	0.3177	0.0704	4.505	0	0	Yes
H3	EB ->RE	0.0413	0.0404	0.0832	0.4968	0.6194	0.3097	No
H4	TB ->RE	0.1317	0.1322	0.0799	1.6491	0.0994	0.0497	Yes
H5	TB ->EB	0.2367	0.2407	0.0768	3.0797	0.0021	0.0011	Yes
H6	RB ->RE	0.5705	0.5649	0.0738	7.7281	0	0	Yes
H7	RB ->RE	0.3249	0.3236	0.0641	5.0687	0	0	Yes

Note: SB = social barriers; EB = economic barriers; TB = technological barriers; RB = regulatory barriers; RE = deployment of renewable energy.

Hypotheses H1 highlights the influence of social barriers on the deployment of renewable energy. The effect of social barriers is moderately significant with *(t-value = 1.8749) and (β=0.1063, p < 0.01)* thus hypothesis H1 got accepted. This shows that social barriers have a moderate influence on the deployment of renewable energy. Earlier studies (Paravantis et al., 2014) have advised that future studies be conducted to determine whether renewable energy is socially accepted. In our study, the positively related t-value testifies to a positive level of significance, implying that social barriers are still a hindrance to the deployment of renewable energy. Fig. 3 below shows the Social barriers with associated path coefficients.

Hypothesis H2 highlights the impact of social barriers on economic barriers. The effect of social barriers is highly significant with *(t- value = 4.505) and (β=0.317, p < 0.01)* was accepted. This indicates that the parameters, such as opportunity cost and opposition by residents, strongly influence economic parameters. Earlier studies (Jianjun and Chen, 2014) have supported that social barriers impact economic parameters. However, the earlier studies did not conduct research to understand the strength of the impact. Through our survey, we have determined that social barriers do have a strong correlation with the economic barriers associated with the implementation of renewable energy.

Hypothesis H3 tested the influence of economic barriers on the deployment of renewable energy. The statistical results with *(t- value = 0.4968) and (p > 0.01)* as not supported. This indicates that the parameters of economic barriers do not influence the deployment of renewable energy directly. Previous studies (Boie et al.,
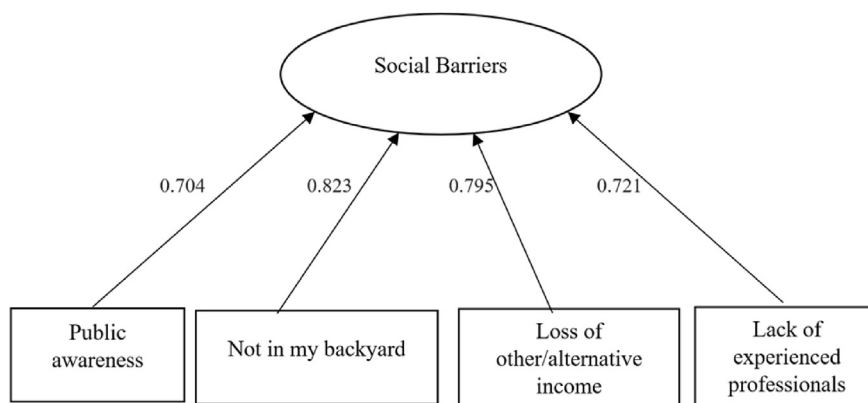
Fig. 3. Social barriers with associated path coefficients.

2014) have pointed out that financial and economic parameters act as hurdles in the wide usage of renewable energy. However, this research contradicts the earlier findings. Fig. 4 below depicts the Economic barriers with associated path coefficients.

Hypothesis H4 tested the effect of technological barriers on the deployment of renewable energy. The effect of technological barriers is moderately related *(t- value = 1.6491) and (β=0.1317, p < 0.01)* thus H4 is accepted. This indicates that technological barriers are moderately significant in the deployment of renewable energy. Earlier research (Gullberg et al., 2014) has pointed out that lack of technology advancement has created obstacles for implementing renewable energy. This research paper corroborates the findings of previous studies. Fig. 5 shows the Technological barriers with associated path coefficients.

Hypothesis H5 examined the impact of technological barriers on economic barriers. The effect of technological barriers on economic barriers is highly significant, with a *(t- value = 3.0797) and (β=0.2367, p < 0.01)* thus hypothesis H5 is accepted. This
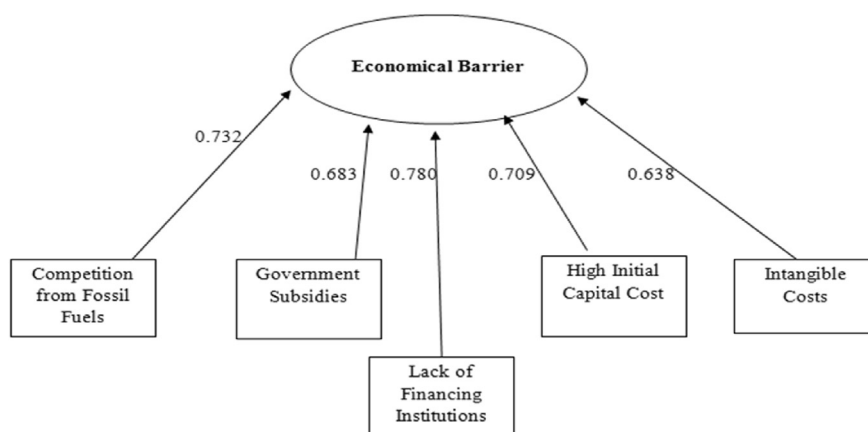

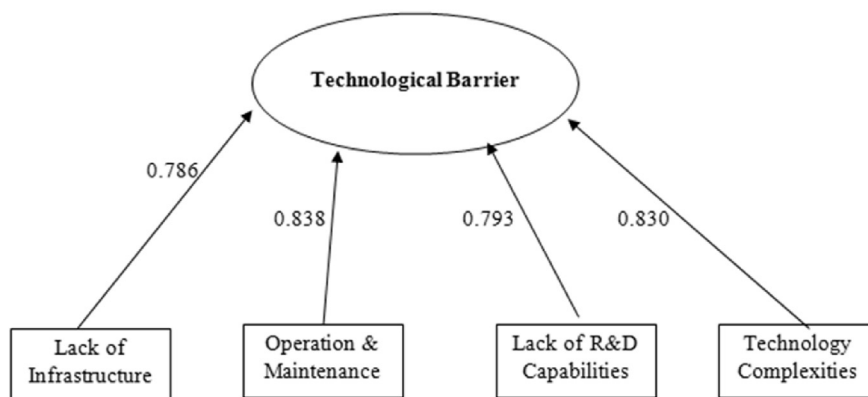**Fig. 4.** Economic barriers with associated path coefficients.

Fig. 5. Technological barriers with associated path coefficients.

indicates that the technological barriers have a highly significant impact on economic barriers. Earlier research (Zyadin et al., 2014) pointed out that lack of research and development has kept the costs of renewable energy higher compared to energy produced from fossil fuels. This study validates the findings of earlier studies.

Hypothesis H6 examined the effects of regulatory barriers on the deployment of renewable energy. Once again, the effect of regulatory barriers on the deployment of renewable energy is highly significant, as the *(t- value = 7.7281) and* $(\beta=0.5705, p < 0.01)$. This indicates that regulatory barriers have a significant impact on the implementation of renewable energy. Earlier studies (Jing, 2016) discuss how government policies and administration affect the usage of renewable energy. However, the earlier studies were specific to a country. This study fills the gap by conducting research globally and taking all major countries into consideration. Fig. 6 shows the Regulatory barriers with associated path coefficients.

Hypothesis H7 argued for the effects of regulatory barriers on economic barrier parameters. The effect of regulatory barriers on economic barriers is once more highly significant with *(t- value = 5.0687) and* $(\beta=0.3249, p < 0.01)$ thus supported
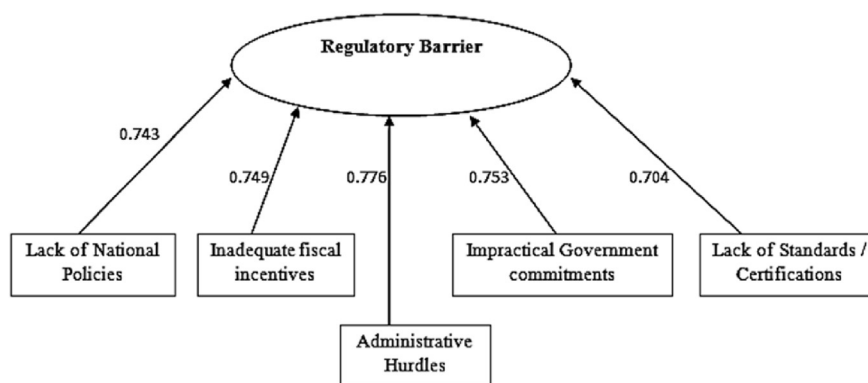

Fig. 6. Regulatory barriers with associated path coefficients.

strongly. This indicates that regulatory barriers have a highly significant impact on economic barriers regarding the deployment of renewable energy. Conversely, the earlier literature (Harrison, 2015) discusses how regulatory and government policies affect the implementation of renewable energy. This research fills the gap by establishing a strong association between regulatory and economic barriers.

7. Discussion & conclusion

Research was conducted to understand the barriers associated with the deployment of renewable energy and the benefits of overcoming these barriers. This research answers all the questions identified as part of the research objective.

Firstly, the factors affecting the deployment of renewable energy were identified and grouped into social, economic, technological and regulatory barriers. This research shows that social, technological and regulatory barriers have a strong influence on the deployment of renewable energy, while economic barriers, though not directly influencing it, and significantly influence it indirectly. Fig. 7 indicates the Deployment of renewable energy and its path coefficients.

Secondly, in the structural equation model above, the path coefficient of user-friendly procedures is 0.808, that of stakeholder satisfaction is 0.81, successful R&D ventures is 0.86 and cost savings is 0.80. Since the path coefficient for the entire four constructs is equal or greater than 0.80, this implies that breaking barriers in the deployment of renewable energy has a strong impact on all four constructs (user-friendly procedures, stakeholder satisfaction, successful R&D ventures and cost savings).

Finally, the research confirms that political implications have a big impact on the deployment of renewable energy. Technological barriers are preventing renewable energy from being efficient and preventing it from being cost effective. Social
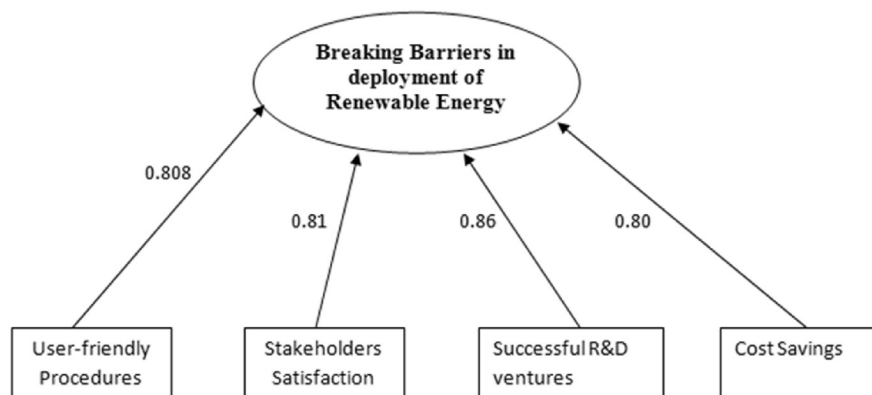

Fig. 7. Deployment of renewable energy and its path coefficients.

awareness and opposition also have a positive impact on the deployment of energy. These results are in line with the theory of diffusion and answer the third question of the research objective.

7.1. Implications for renewable energy industry

In our research, we have studied the impact of various barriers on the deployment of renewable energy. By breaking research and development-related barriers, organizations will be able to invest greatly in developing advanced technologies that can optimize usage of renewable energy and make renewable energy appear more lucrative. With less polluting and lower tariff energy solutions being made available to local people, and higher profits for manufacturers, this will create an atmosphere where all stakeholders are satisfied. Breaking red tape in government procedures will lead to generating interest among investors in renewable energy projects and, by breaking the barriers to the deployment of renewable energy, a greater number of projects will start up. This will help to achieve economies of scale and will bring down operation and maintenance costs. By supporting further innovative technological advancements, more efficient plants will be developed which may require smaller portions of land. Modern technologies will also make offshore wind/solar farms economically feasible.

Though renewable energy would prevent degradation of the environment, however, a small fraction of the ecosystem will still be affected: for example, in the case of offshore wind farms, underwater marine life might be disturbed.

7.2. Limitations and future research

In this research, we have considered the presence of four barriers as factors preventing the successful deployment of renewable energy globally; however, it is reasonable to expect that not all the barriers will be present in each country and there could be some new barriers that have not yet been conceptualized. Though this research has been conducted to understand the global perception, the data collected constituted only 9.8 per cent from Europe, 6.3 per cent from America, 5.9 per cent from the Middle East and Africa, and five per cent from Australia. The research conducted was mainly based on data collected from the Asia Pacific region. Cultural characteristics of Asians can be considered to be different from those of other countries; hence it is advised to practise caution when generalizing the findings in the context of renewable energy.

Finally, regarding future research, further study is required to understand and compare the impact of barriers to renewable energy in developing and developed countries.

7.3. Conclusion

In the long run, due to increasing awareness of environmental damage, conventional power generation based on exhaustible fuels (oil, coal and gas) is generally considered unsustainable. Alternative energies that have minimal impact on the environment and are inexhaustible, such as renewable energy, can be a solution to the long-fought sustainability problem. However, despite on-going awareness of the manifold advantages of renewable energy, the diffusion of renewable energy is limited globally. This restriction has been attributed to social, economic, technological and regulatory barriers.

This research presents the impact of social, economic, technological and regulatory barriers on the deployment of renewable energy and how these barriers are interrelated. Focusing on factors influencing barriers and the deployment of renewable energy, a research model was developed and tested by analysing the data collected from 223 respondents. Respondents were experienced professionals from the energy industry. The findings show that social barriers have a positive impact while technological and regulatory barriers have a very significant impact on the deployment of renewable energy. However, this research shows that economic barriers do not directly impact the deployment of renewable energy, but are interrelated with social, technological and regulatory barriers, thus indirectly affecting the deployment of renewable energy. The simultaneous increase in energy demand and the negative impact of fossil fuels on the environment underscores the need for energy production from renewable energy sources. Renewable energy sources strike a perfect balance between economic, technical and environmental considerations, and contribute to a more sustainable development that will favour future generations.

Declarations

Author contribution statement

Seetharaman Conceived and designed the experiments.

Krishna Moorthy: Performed the experiments, Analyzed and interpreted the data, Wrote the paper.

Nitin Patwa: Performed the experiments.

Saravanan: Analyzed and interpreted the data.

Yash Gupta: Contributed reagents, materials, analysis tools or data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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References

Ahlborg, H., Hammar, L., 2014. Drivers and barriers to rural electrification in Tanzania and Mozambique: Grid-extension, off-grid and renewable energy technologies. Renew. Energy 61, 117–124.

Ansari, M.F., Kharb, R.K., Luthra, S., Shimmi, S.L., Chatterji, S., 2016. Analysis of barriers to implement solar power installations in India using interpretive structural modeling technique. Renew. Sustain. Energy Rev. 27, 163–174.

Arnold, U., 2015. Economic risk analysis of decentralized renewable energy infrastructures: A Monte Carlo simulation approach. Renew. Energy 77, 227–239.

Azad, A.K., Rasul, M.G., Khan, M.M.K., Ahasan, T., Ahmed, S.F., 2014. Energy scenario: Production, consumption and prospect of renewable energy in Australia. J. Power Energy Eng. 2, 19–25.

Bhandari, B., Lee, K., Lee, G., Cho, Y., Ahn, S., 2015. Optimization of hybrid renewable energy power systems: A review. Int. J. Precis. Eng. Manuf. Green Technol. 2 (1), 99–112.

Boie, I., Fernandes, C., Frías, P., Klobasa, M., 2014. Efficient strategies for the integration of renewable energy into future energy infrastructures in Europe:An analysis based on transnational modeling and case studies for none European regions. Energy Policy 67, 170–185.

Byrnes, L., Brown, C., Foster, J., Wagner, L.D., 2013. Australian renewable energy policy: Barriers and challenges. Renew. Energy 60 (1), 711–721.

Cable, D.M., Cable, D.M., Derue, D.S., 2014. The convergent and discriminant validity of subjective fit perceptions. J. Appl. Psychol. 87 (5), 875–884.

Campbell, D.T., Fiske, D.W., 1959. Convergent and discriminant validation by the multitrait-multimethod matrix. Psychol. Bull. 56 (2), 81.

Chauhan, A., Saini, R.P., 2015. Renewable energy based off-grid rural electrification in Uttarakhand state of India: Technology options, modelling method, barriers and recommendations. Renew. Sustain. Energy Rev. 51 (December), 662–681.

Cho, C., Yang, L., Chu, Y., Yang, H., 2013. Renewable energy and renewable R&D in EU countries. Cointegrat. Anal. 2 (1), 10−16.

Darnton, A., 2008. Reference report: An overview of behaviour change models and their uses. Government Social Research Behaviour Change Knowledge Review, UK.

Dulal, H.B., Shah, K.U., Sapkota, C., Uma, G., Kandel, B.R., 2013. Renewable energy diffusion in Asia: Can it happen without government support? Energy Policy 59 (April), 301−311.

El-katiri, L., 2014. A roadmap for renewable energy in the Middle East and North Africa.

Emodi, V.N., Yusuf, S.D., Boo, K., 2014. The necessity of the development of standards for renewable energy technologies in Nigeria. Smart Grid Renew. Energy 5 (November), 259−274.

Goldsmiths, K.R., 2015. Barriers and solutions to the development of renewable energy technologies in the Caribbean. (April).

Gullberg, A.T., Ohlhorst, D., Schreurs, M., 2014. Towards a low carbon energy future: Renewable energy cooperation between Germany and Norway. Renew. Energy 68 (August), 216−222.

Halabi, M.A., Al-qattan, A., Al-otaibi, A., 2015. Application of solar energy in the oil industry: Current status and future prospects. Renew. Sustain. Energy Rev. 43, 296−314.

Harrison, B., 2015. Expanding the renewable energy industry through tax subsidies using the structure and rationale of traditional energy tax subsidies. Univ. Muichigan J. Law Reform 48 (3).

Henseler, J., Dijkstra, T.K., Sarstedt, M., Ringle, C.M., Diamantopoulos, A., Straub, D.W., Calantone, R.J., 2014. Common beliefs and reality about PLS: Comments on Rönkkö and Evermann (2013). Organ. Res. Methods 17 (2), 182−209.

Huang, S., Lo, S., Lin, Y., 2013. To re-explore the causality between barriers to renewable energy eevelopment: A case study of wind energy. Energies 6 (9), 4465−4488.

Izadbakhsh, M., Gandomkar, M., Rezvani, A., Ahmadi, A., 2015. Short-term resource scheduling of a renewable energy based micro grid. Renew. Energy 75 (March), 598−606.

Jianjun, J., Chen, D.S., 2014. Willingness to pay for renewable electricity: A contingent valuation study in Beijing, China. Energy Policy 68 (May), 340−347.

Jing, E., 2016. Development of renewable energy in Australia and China: A comparison of policies and status. Renew. Energy 85 (January), 1044−1051.

Karakaya, E., Sriwannawit, P., 2015. Barriers to the adoption of photovoltaic systems: The state of the art. Renew. Sustain. Energy Rev. 49, 60−66.

Karatayev, M., Hall, S., Kalyuzhnova, Y., Clarke, M.L., 2016. Renewable energy technology uptake in Kazakhstan: Policy drivers and barriers in a transitional economy. Renew. Sustain. Energy Rev. 66, 120−136.

Lacerda, J.S., van den Bergh, J.C.J.M., Stern, D.I., 2014. International diffusion of renewable energy innovations: Lessons from the lead markets for wind power in China, Germany and USA.

Lewin, K., 1951. Field theory in social science.

Marshall, A.L., 2014. International physical activity questionnaire: 12-country reliability and validity.

Nasirov, S., Silva, C., Agostini, C.A., 2015. Investors' perspectives on barriers to the deployment of renewable energy sources in Chile. Energies 8 (5), 3794−3814.

Nesamalar, J.J.D., Venkatesh, P., Raja, S.C., 2017. The drive of renewable energy in Tamilnadu: Status, barriers and future prospect. Renew. Sustain. Energy Rev. 73 (June), 115−124.

Ohunakin, O.S., Adaramola, M.S., Oyewola, O.M., Fagbenle, R.O., 2014. Solar energy applications and development in Nigeria: Drivers and barriers. Renew. Sustain. Energy Rev. 32, 294−301.

Painuly, J.P., 2001. Barriers to renewable energy penetration; a framework for analysis. Renew. Energy 24 (1), 73−89.

Paravantis, J., Stigka, E., Mihalakakou, G., 2014. An analysis of public attitudes towards renewable energy in Western Greece. Renew. Sustain. Energy Rev. 32 (March 2015), 100−106.

Rawat, D., Sauni, P., 2015. Importance and prospects of renewable energy: Emerging issues in India. Int. J. Art Hum. Sci. 2 (4), 11−18.

Raza, W., Saula, H., Islam, S.U., Ayub, M., Saleem, M., Raza, N., 2015. Renewable energy resources: Current status and barriers in their adaptation for Pakistan. J. Bioprocess. Chem. Eng 3 (3), 1−9.

Rogers, Everett M., 1983. Diffusion of innovations, third ed. Free Press of Glencoe, New York.

Rogers, E.M., 2003. Diffusion of innovations, fifth ed.

Sahin, I., 2006. Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. Turk. Online J. Educ. Technol. 5 (2), 14−23.

Sarstedt, M., Henseler, J., Ringle, C.M., 2011. Multigroup analysis in partial least squares (PLS) path modeling: Alternative methods and empirical results. In: Sarstedt, M., Schwaiger, M., Taylor, C.R. (Eds.), Measurement and research methods in international marketing (Advances in international marketing, volume 22). Emerald Group Publishing Limited, pp. 195−218.

Schreiber, J.B., Nora, A., Stage, F.K., Barlow, E.A., King, J., 2015. Reporting modeling analysis and confirmatory results: Equation factor review. J. Educ. Res. 99 (6), 323−337.

Sen, R., Bhattacharyya, S.C., 2014. Off-grid electricity generation with renewable energy technologies in India: An application of HOMER. Renew. Energy 62, 388−398.

Stokes, L.C., 2013. The politics of renewable energy policies: The case of feed-in tariffs in Ontario, Canada. Energy Policy 56, 490−500.

Sun, P., Nie, P., 2015. A comparative study of feed-in tariff and renewable portfolio standard policy in renewable energy industry. Renew. Energy 74 (February), 255−262.

Suzuki, M., 2013. What are the roles of national and international institutions to overcome barriers in diffusing clean energy technologies in Asia? Matching barriers in technology diffusion with the roles of institutions. Retrieved from: http://cdn.intechopen.com/pdfs/43765/InTech-What_are_the_roles_of_national_ and_international_institution s_to_ overcome_barriers_in_diffusing_clean_energy_ technologies_in_asia_matching_barriers_in_technology_diffusion_with_the_roles_ of_institutions.pdf.

Weitemeyer, S., Kleinhans, D., Vogt, T., Agert, C., 2014. Integration of renewable energy sources in future power systems: The role of storage. Renew. Energy 75, 14−20.

Weyland, K., 2005. Theories of policy diffusion lessons from Latin American pension reform. World Polit. 57 (02), 262−295.

Zhang, H., Li, L., Zhou, D., Zhou, P., 2014. Political connections, government subsidies and firm financial performance: Evidence from renewable energy manufacturing in. Renew. Energy 63, 330−336.

Zhao, Z., Chang, R., Chen, Y., 2016. What hinders the further development of wind power in China ? A socio-technical barrier study. Energy Policy 88 (January), 465−476.

Zyadin, A., Halder, P., Kähkönen, T., Puhakka, A., 2014. Challenges to renewable energy: A bulletin of perceptions from international academic arena. Renew. Energy 69 (September), 82−88.