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Commercialization of renewable energy technologies: A ladder building approach

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ABSTRACT

The objective of this study is to investigate how different renewable energy technologies (RETs) can be effectively commercialized in Finland. The country, not being endowed with natural reserves of hydrocarbons, is striving to increase the share of renewable energy generation in its primary energy supplies. Finland has long been involved in the development and innovation of technologically advanced products and services. The recent economic meltdown and decline in the information and communication technology (ICT) sector have triggered the inevitability of developing a sector that can serve as the backbone of the economy in the years to come. Clean technologies offer an excellent opportunity for a technologically advanced country like Finland to become a key player in the emerging market. The country has excellent standing when it comes to innovation input, innovation culture and public R & D in clean technologies; however, it lags behind when it comes to the commercialization of these novel technologies.

This study aims to address the problem by investigating questions such as: What are the key factors that influence the commercialization of RETs in Finland? How do technological, regulatory and market-related factors affect the widespread adoption of RETs in Finland? The study also highlights the significance of support mechanisms and suggests the improvements required, at the micro-level (firms) and macro-level (policies, regulation and infrastructure), to develop a successful RET market in Finland. The findings of the study are presented against the backdrop of existing literature, energy policies, and the data collected from the energy experts in academia, technology firms, utility companies, investment firms, and regulatory bodies. The study has thus identified the factors that are central to the acceleration of RETs commercialization in Finland. Based on the findings, the study presents a comprehensive framework for the commercialization of RETs in Finland.

1. Introduction

Commercialization is considered to be the most important [1–3], and at the same time, least developed part of innovation management [4,5]. The literature is full of evidence indicating the significance of commercialization in the technology's success or failure [6–9]. The successful conversion of an idea into a product or technology is extremely challenging [10]. A staggering number of inventions have failed to become successful products due to a weak commercialization strategy [11,12]. A study conducted by Cierpicki et al. estimated the failure rate of commercialized products to be over one-third of all those introduced in the western economies [13]. Similarly, Stevens and Burley have demonstrated that out of a hundred small R & D projects, only one or two reach the market-launch stage and become successful [14].

Research, development and the introduction of new technology in the market are a costly business, consuming a significant proportion of a firm's resources. The process becomes even riskier if the technology in question is high-tech and the company has invested a significant amount of time and resources in the development process. Chakravorti [15], Chesbrough and Rosenbloom [16] have explained that the resources commitment and the stakes involved make the process pivotal for companies, as it is the stage where the product is launched into the market, exposed to the customers, and is expected to generate revenues. A product's penetration into the market and its success or failure is heavily dependent upon how efficiently the whole process has been carried out. Perez-Bustamante affirms that mastering commercialization is of utmost importance, as it is the last stage of the product innovation chain, through which an innovation is transformed into the final product and becomes a part of mainstream economic activity [17]. According to Aalam et al. commercialization guarantees that the product not only fulfils performance and reliability requirements, but also meets consumer demand and is available at reasonable prices [18]. It is further argued that the successful commercialization process can be a key

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for companies to maximize return on inventions, gain competitive advantage and explore opportunities for trade and market expansion [19].

A significant number of market failures are attributed to the lack of a strategically devised commercialization process, and its significance highlighted by the practitioners are no secret [20]. However, a number of companies, one way or another, tend to find themselves trapped in this phase. This leads us to ask if companies and executives underestimate the importance of commercialization during the technology development phase. The answer to this question in most cases will probably be in the negative. An online survey of over 2000 executives from around the world, working in a wide range of industries, regions, areas of expertise, tasks and responsibilities, found that a significant portion of the professionals considered the step crucial for a company's success and growth [21]. However, more often than not, companies leave a loophole in the process, which can then lead to the failure of the technology in the market. Acknowledging the importance of the process yet failing to deliver has raised researchers' interest in the topic and has prompted them to investigate the reasons behind such failures.

Commercialization, by its very nature, is a complex and multi-faceted phenomenon, requiring extensive research and understanding of the business environment before it can yield the required results. Due to its overlapping nature and the interaction of various actors, players and stakeholders in the process, the phenomenon has been studied through the lens of economics, entrepreneurship, innovation, marketing, transition management, strategic management and international business. This multidisciplinary nature has encouraged researchers of diverse backgrounds to study the process from different perspectives, such as technology development, sociological aspects, socio-technical systems, marketing, consumer behaviour and finance.

Rogers [22] defines commercialization as the conversion of an idea to the product or services for sale in the marketplace. Siegel et al. [23] describe commercialization as the process of converting a new product, processes, and related know-how into a profit-generating venture. According to Aarikka-Stenroos and Lehtimaki [24], commercialization can be seen as the marketing of the innovation with the objective of converting it into a profit-making proposition. Balachandra et al. explain commercialization as a process of bringing technology from the laboratory to market acceptance and use. Furthermore, the notion is unfolded as the formation of a market that can sustain and thrive on its own, without backing and support, on a level playing field with competing technologies, thus helping technologies to avoid being trapped in the 'valley of death'[1] [25]. Cooper has introduced a seven-stage model, asserting that the process starts with the generation of the idea followed by preliminary assessment, concept and product development, trial production and lastly the commercialization phase where the product is launched in the market [1]. Vijay elaborates that commercialization is an arrangement between the key process (imaging, incubating, demonstrating, promoting and sustaining) necessary to develop and sustain the product in the market, combined with sub-processes, facilitating the transition by mobilizing essentials to ensure success at each phase [2].

Contrary to the belief that commercialization is an integrated aspect in each stage of new product development – from idea generation to the product launch and the subsequent sustaining of the market, scholars such as Koen et al. [26], O'Conner et al. [27], and Booz, Alan and Hamilton [28] have considered commercialization as the final stage of product development, predominantly dealing with measures such as marketing strategies and their implementation, introduction of the product to market and the launch of the technology. However, findings of recent research have highlighted that many decisions and activities seemingly performed in the earlier phases of the development process do have an impact on the overall commercialization and success of a technology [29], strengthening the argument that the process evolves simultaneously and commercialization and product development are interlinked [3,24]. In the light of the above-mentioned definitions, irrespective of the orientation towards the phenomenon-stage based approach or the process-driven approach, it is obvious that a scientific discovery or an invention does not become an innovation until it has been successfully commercialized [19,30], diffused [22,31] and sustained in the market [2].

The process of commercialization can be tiresome and lengthy, as can be observed in the cases of the jet engine, television and fluorescent lamps, where it took a number of years[2] before these technologies were actually commercialized [32]. These cases reveal that it is not just the scientific discovery or the benefit a technology offers that will ensure its success or rapid adoption [33]. There are a number of forces at play that determine the future of a technology [34]. There have been cases where technologically advanced products were overshadowed by inventions that were considered inferior in terms of technological capabilities and benefits, but had benefited from a better commercialization process [9,35]. This leads us to the discussion of what companies should do to avoid failures and achieve success. According to Zahra and Nielsen [36], the commercialization of a technology can be improved by developing efficiencies in the technology development process. Overall success lies is the sum total of successes achieved at each stage of the new product's development [2].

Ettlie [37] emphasized that an organization should be strong when it comes to core knowledge and organizational capabilities [38]. Many authors have embraced the issue and have studied the ways through which competencies can be developed at the firm level [39,40]. According to Teece et al. [39], capabilities can be enhanced by developing the skills and knowledge of the personnel involved, bringing improvements in the overall processes, systems and equipment. Smith et al. [41] have emphasized that the knowledge and expertise of the individuals can lead firms to gain competitive advantage. Menon et al. elaborate that developing the culture of innovation [42] and engaging creative individuals who have diversified knowledge and skills can enhance overall efficiency [23]. In addition to developing internal capabilities, it may also be a good idea to involve external partners in order to augment the skills-base, bridge any gaps, and gain complementarities. A study conducted by Manoukian et al. [43] highlights that the engagement of an external partner can help in developing the process and improving the overall performance of the organization. Chen [44] and Snow et al. [45] have shown in their studies that the organization attained success by integrating an external partner in the development process. Being part of ecosystems [46] and obtaining the services of business incubators [47], an accelerator programme [48] and facility parks [49] can also help companies develop the product further and ensure the efficient use of the resources. Universities and research centres are home of innovative ideas and creative minds. Collaboration with academic institutions and research centres can be very useful in the development and successful commercialization of technology [50]. Similarly, the involvement of venture capital organizations can also be useful in improving the overall process of commercialization [46]. Small- and medium-sized companies often find themselves in a situation where they are lacking the financial resources to perform necessary product development features and launch the technology in the marketplace [51]. Cooperation with such organizations will not only help address the financial issues, but can also complement the firm with the skills and knowledge necessary to commercialize the technology successfully.

It is equally important to have the right dissemination scheme in place. This aspect of a commercialization strategy is more concerned with how the technology should be launched in the marketplace. The literature

[1] In transition from the demonstration to the commercialization phase where the cost of production is higher and the market penetration is low.

[2] 79 years for the fluorescent lamp, 22 years for the television and 14 years for the jet engine

suggests that the primary choice of commercialization strategy is influenced by the type of innovation and related commercial risk associated with introducing that innovation to the marketplace, which may be concerned with costs, the product itself and the market [6]. In turn, the level of risk determines whether the strategic choice involves some dependence on third parties or whether the technology entrepreneur can pursue their strategy independently of other players in the marketplace [52]. The strategy may also be influenced by the overall environment in which a firm operates. Gans and Stern articulates that firms operating in strict regime, having strong intellectual property protection, and owning the required resources may prefer going into the market on their own, compared with the scenario in which the protection environment is relatively less stringent and the dangers of replication are high. In the latter case, companies tend to look for partnership and joint ventures with established firms [10]. Likewise, the nature and size of the firm can also be a driving factor behind these choices. Zoltan and David [53] and Libaers et al. [54] suggest that big firms usually face problems with a rigid hierarchal structure, which may compromise their position in a marketplace that is rapidly evolving and requires quick decision-making. The preferred choice may be to enter the market by means of spin-offs and subsidiaries in order to achieve the flexibility required to compete with innovative small-sized organizations that enjoy flexible working structures [16,55].

Many scholars have also attributed the time to market [42], the portfolio of the products [9] and launching products at the right time [56] as key to commercialization success. Li et al. found that the companies that have introduced more products in the market compared with their competitors had achieved higher success [57]. Similarly, companies entering the market early with breakthrough technologies might enjoy the 'first mover' advantage [9]. However, a number of scholars have stressed that getting first to market may not guarantee success alone, especially if the nature of the technology is disruptive, as followers may imitate or complement the original technology by improving it to the level where it can better serve the customer's needs [58,59]. Moreover, in today's competitive world, internationalization can play an important role in a firm's ability to commercialize a technology successfully. Companies that can overcome the obstacles and enter the international market will have a larger market to serve, and addressing its needs in the right manner can enhance the chances of successful technology commercialization. From the discussion, we can infer that a successful commercialization process can be divided into three basic aspects: i) development of a technology that has a potential of serving market needs; ii) using a channel that suits the technology and the company best; iii) in a manner that the technology is accepted by the customers. Based on this, we can define commercialization as a process of developing a functional technology, complemented with the features required by its target market, which is supported by an effective dissemination strategy that have a probability of thriving in the marketplace.

Notable work has been done in the past couple of decades on technology commercialization and exploring the factors that hinder its success [2,22,33,60,61]. However, the commercialization of renewable energy technologies is a thing of the recent past, and scholars have started to focus more on how RETs can be made part of the energy system. There is a wealth of literature highlighting the massive energy generation potential of renewable energy sources [62–65]. However, to this end, the share of RETs in the world energy mix is insignificant [66,67]. It has been debated that the low proportion of renewable energy in the global energy supply is no longer because of their technical potential alone [68–71], but rather a consequence of how these technologies are commercialized [71]. Commercialization becomes important in the case of RETs, as without commercial status these technologies will neither gain consumers' confidence nor benefit from the dynamism of the private economy [25].

1.1. Commercialization of renewable energy technologies

The commercialization of renewable energy technologies is even more tactical and troublesome as there are some additional barriers that these technologies have to surpass before they can achieve success. According to Aalam et al. the successful diffusion of RETs depends on a variety of factors, including, but not limited to, availability of renewable energy resources, remoteness and isolation, socio-economic conditions, affordability of technology, willingness to pay and the level of awareness [18]. Amigun et al. studied the potential of biomass in Africa and identified the factors that have caused hindrances in its widespread diffusion and adoption. The barriers identified are categorized as technical and non-technical. The high cost of raw materials and other economic constraints are considered as the technical barriers, whereas non-technical barriers include policy, legal, financial, institutional, cultural and societal constraints [72]. Sustainable energy technologies are primarily different from the standard technologies due to the nature of the industry, the type of technologies, the level of awareness, and the need to have the right public policies and infrastructure in place.

Renewable energy technologies are known to have the characteristics of disruptive technologies. These technologies are fundamentally different from preceding technologies serving similar markets. Their success in the commercialization process becomes dependent on a number of actors operating at various levels, including, but not limited to, the government, local bodies, investors, entrepreneurs, society, stakeholders and the customers. It is evident from the literature that, more often than not, the originators of disruptive technologies are small-sized organizations. These companies are usually strong in technology development but often struggle to commercialize on their own [73]. At present, in the majority of the countries, energy infrastructure is centralized and operated by the large utilities companies, owned by either the state or very large corporations. Renewable energy technologies cannot be adopted on a large scale unless the supporting infrastructure is in place, which often requires great motivation and investment from several parties. Moreover, some of the renewable energy technologies have not yet fully matured or gone through the cycle of development. These technologies face natural reluctance from customers, as the likelihood of adoption increases once the technology meets performance and reliability requirements [74]. Olleros argues that commercialization becomes extremely vital for the technologies that are emerging and are in a relatively early phase of development [75].

Verbruggen et al. assert that economics and market-related factors are extremely important and require fair consideration, while formulating strategies for the commercialization of RETs [76]. It is argued that in a period when technological progress is closely tied to commerce and finance, many renewable energy technologies trail behind conventional technologies in terms of adoption, despite the long-standing efforts to promote them [25]. Golder et al. [77] believe that the majority of people in academia overlook the economic, environmental and market-related factors when discussing the true potential of RETs. The effectiveness of RETs and the role they can play cannot be determined solely by the world's resources. In the light of the current development of various technologies, assuming normal economics and investment criteria apply, the contribution from most of the renewable energy technologies is likely to be only a small proportion of its potential. [25] states that the technologies that are superior in terms of performance, initial cost, quality, reliability and user friendliness have achieved a fair level of market penetration. However, many of the RETs have failed to gain sizeable market share, as being environmentally friendly and energy efficient alone will not help them to sustain the market for a long period and there is a need to bring the cost down to a level where it becomes competitive with the

existing solutions. To this end, the majority of RETs cannot compete with conventional technologies based on economics alone, making their commercialization imperative as they may struggle to survive otherwise. Nonetheless, it is widely believed that the existing regime favours conventional technologies and makes their use cheaper compared with ambient energy technologies [78]. It is argued that if the cost of polluting the environment is imposed and the utilities are required to internalize the externalities, the cost of energy generation from renewables will become competitive [79]. Therefore, in the existing scenario, the role of subsidies and support schemes becomes very important. The long-term benefits that the RETs can offer in the form of energy security [80], sustainable development [81] and efficient use of indigenous resources [82] put pressure on governments to ensure their integration into the energy system. Governments are constantly looking to devise the support mechanism and strategies to ensure the adoption of environmentally friendly technologies. Walters and Walsh [6] and Wiser [83] suggest that renewable energy markets tend to develop more because of supportive public policies and less through the efforts of competitive and commercial interests alone. The study conducted by Lehtovaara et al. on the role of governmental support schemes and market penetration found that well-structured support schemes and subsidies are essential to ensure the successful commercialization of renewable energy technologies [84].

Furthermore, companies should develop innovative business models that can not only make the business proposition profitable for the incumbent firm but also make it viable for the customer to purchase the technology. A traditional model of sale purchase may not be very effective for ensuring the enhanced diffusion of these technologies [85]. Companies need to look beyond the conventional measures of probing investments in renewables like payback time and net present value. The initial cost of these technologies has been seen as one of the main hurdles in their adoption, so companies that can devise plans where the initial cost is dispersed during the period of use are more likely to gain customers' trust in the technology. From the above discussion, it is evident that successful commercialization is the right mix of technical, market and regulatory factors, and if any of the elements is missing, the success and widespread adoption of the technology becomes extremely challenging (Fig. 1).

1.2. Objective and structure of the study

The objective of this study is to investigate how different renewable energy technologies can be effectively commercialized in Finland. A number of studies have focused on the commercialization of technologies [86–89], while some have focused on high-tech industry [4,90,91] and disruptive innovations [92–94]. However, the literature focusing on the commercialization of renewable energy technologies is rather limited. This limited stream of research has attempted to investigate the phenomenon from the perspective of the resources [72], the role of public policies [95], technology type [71], financing [6], marketing [96], demonstration [97], business models [98] and collaboration [99]. However, there have been very few studies focusing on the commercialization environment of renewable energy technologies as a whole [25,97], and seldom from Finland's perspective. This study contributes to extant literature by presenting a comprehensive review of the commercialization of renewable energy technologies in Finland and attempts to investigate how the technical, economic and environmental factors are actually playing a role from the country's perspective. The main research question of the study is thus: What are the key factors that influence the commercialization of RETs in Finland? This research seeks to address this question by identifying the drivers and barriers affecting the process, and presenting a framework for addressing these barriers in order to foster the process of commercialization. The study conclude that the country has fairly strong standing when it comes to research, developments, technological know-how and basic infrastructure; however, there is a need to improve coherence between stakeholders, financing facilities, internationalization, and collaboration between industry and academia. The study also highlights the significance of support mechanisms and suggests the improvements required, at the micro-level (firms) and macro-level (policies, regulation and infrastructure), to develop a successful RETs market in Finland.

The remaining parts of the study are structured as follows. Section 2 sheds light on how the review was conducted. Section 3 discusses the Finland's energy outlook and is followed by Section 4 on RETs and their significance for the country. Section 5 identifies the factors influencing the commercialization of RETs in Finland. Section 6 presents a discussion and proposes a framework for the enhanced commercialization of RETs. Lastly, in Section 7 the limitations of the studies are discussed and in Section 8 the conclusion of the study is presented.

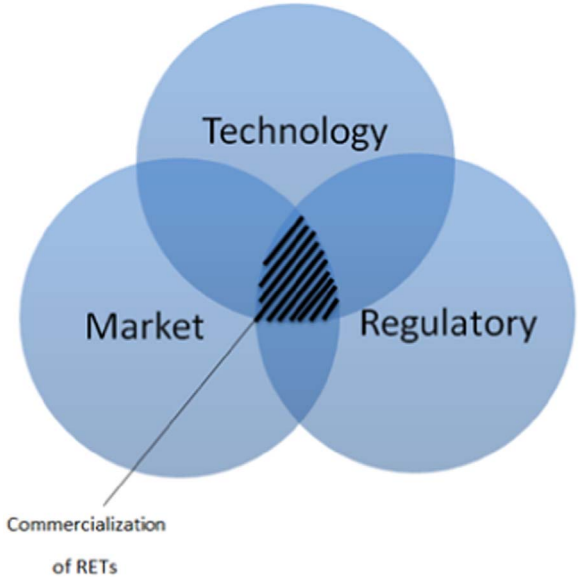

Fig. 1. Commercialization of renewable energy technologies.

2. Methods and research setting

The basic research questions of the study (factors influencing the commercialization of RETs), the exploratory nature of this research, and the aim of studying the phenomenon in its natural setting make the in-depth qualitative case study a suitable approach for this type of research. A case-study methodology can be applied in various contexts, having multiple units of analysis, and can rely on different means for data collection and investigations, such as ethnography, longitudinal studies, interviews, observations and secondary sources of data [100]. Since the study seeks to explore the commercialization process as a whole, the research could not have been confined to a single organization, but required input from the multiple actors and stakeholders involved in the process. In our case, confining the study to a single unit increased the probability of leading to biased and less accurate results. Therefore, the study has incorporated input from different actors and players, such as energy technology companies, financing companies, regulatory bodies, government agencies, utility companies, and experts from academia, research institutes, customers and other stakeholders involved in the process. This approach has helped us in gaining an in-depth understanding and in constructing a comprehensive picture of the overall process by listening to the diverse voices and exploring the phenomenon through a diverse range of lenses. The primary data collection was conducted through semi-structured interviews with the participants. The data triangulation technique was adopted to ensure accuracy, obtaining a detailed and balanced picture of the situation

[101]. Published literature, policies, reports and industry analysis were used as the secondary sources of data. A comprehensive review was conducted based on the collected data and key factors were identified that are central to the acceleration of RETs' commercialization in Finland. The relevant excerpts were selected to establish the links with devised performance indexes, as suggested by [102]. This approach not only creates the links between the data and analysis, and demonstrates the assessment of the quality of cases, but also allows the reader a deeper understanding and overall picture of the context.

3. Energy consumption in Finland

Finland is a Nordic country, located in the northern part of Europe, sharing its border with Norway to the north, Russia to the east, Sweden to the west and to its south Estonia, which lies across the Gulf of Finland. The country is fairly big, the eighth largest in Europe, with a land area of approximately 338,145 km^2 and 5.5 million inhabitants. The majority of its territory, over one-third, lies above the Arctic Circle, which makes its weather relatively colder than that of its neighbouring countries. It is sparsely populated, with the majority of its population residing in the southern part of the country. Finland's cold climate, scattered population, highly industrialized economy, urban structure and high standard of living make it one the highest per-capita energy consuming country on the planet [103].

Finland's existing energy mix is quite diversified and its generation comes from both conventional sources and renewables (Fig. 2); however, the higher level of fossil fuel consumption is still a great concern [104]. Finland, not being endowed with natural reserves of hydrocarbons, imports the majority of the fuel it consumes. The frequent fluctuation in prices and its dependence on external countries not only hinders economic development plans [46,105], but also presents a great concern for the energy security of the country.

The government is developing policies and strategies to drive the country towards a decarbonized economy [106]. Finland has an ambitious plan to increase the share of renewable energy in its final consumption to 38% by the year 2020 [103]. The long-term objective of reducing emissions, increasing the share of indigenous sources and enhancing energy security may not be achieved without developing cleaner sources of energy generation and consumption. The Ministry of Employment and the Economy (MEE) suggests that the adoption of cleaner technologies can save the country around $3–5 billion in the future [107]. Furthermore, being a part of the EU, Finland needs to develop policies and strategies that comply with the EU's environmental regulations. In this regard, Finland is among the successful European states that are on their way to achieving the EU's 2020 objectives. Finland's energy and environmental policy stresses the need for substituting fossil fuels and electricity imports with indigenous renewable energy sources [108]. The Finnish Energy Industries stated that the country's heavy reliance on energy presents an opportunity and the steps taken in the right direction are bound to generate favourable outcomes [109].

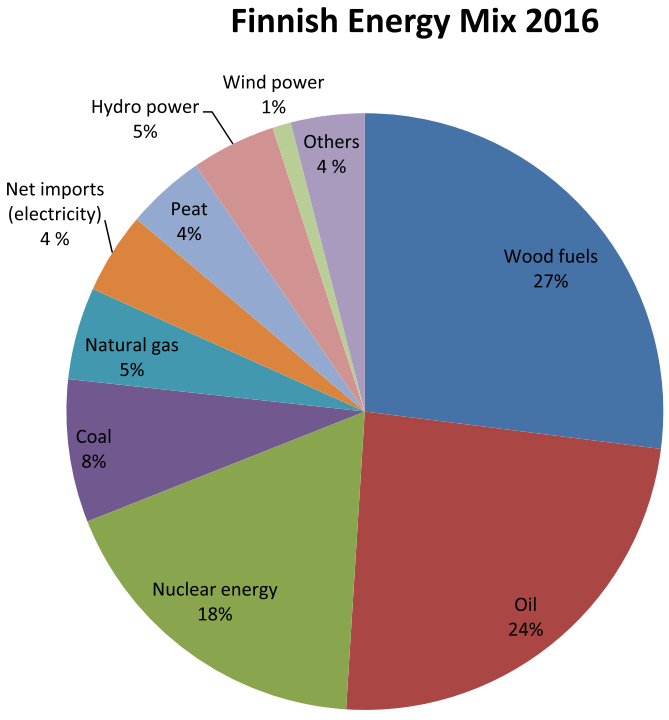

Fig. 2. Finnish energy mix.
Source: Statistics Finland, Energy.

4. Renewable energy technologies in Finland

The concerns surrounding sustained development without compromising the environment have led to the development of cleantech industry. The shift in focus of international policies towards the successful establishment of sustainable energy technologies has made cleantech one of the fastest growing sectors globally. In the year 2013, the size of the market reached over $1600 billion, roughly 6% of the world's GDP [108]. The year 2014 witnessed growth in the investments made in renewable power and fuels, reaching over $270 billion, a rise of 17% since the previous year. Europe is a forerunner in the development of renewable energy technologies and has invested over 57 billion dollars during the year. The sector has witnessed exponential growth and almost half of all the new power generation capacity added worldwide has come from renewables, making the cumulative capacity over 100 GW for the first time in history [110].

Finland, having a strong industrial base, is in an excellent position to become a key player in the emerging renewable energy technology market. The country's vision of improved environmental conditions, compliance with international environmental regulations and strict emission reduction targets is a strong force behind the growth of Finnish cleantech industry. Investments in RETs and expansion in the local industry are important needs of an energy-intensive country like Finland, as reasonable energy prices are important for the stability and growth of the economy [108]. Besides, the demand of sustainable energy technologies is increasing globally, especially in the developing world. According to the United Nations Environmental Programme (UNEP), the developing countries' investment in cleaner technologies increased by 36% in 2014, compared with the previous year, reaching $131 billion [110]. The combination of soaring energy needs, less developed energy infrastructure and a weak industrial base in the emerging economies offers an excellent opportunity for a country like Finland to target the market and become a leader in the industry.

Technology is imperative in attaining sustainability, as the transition towards a low-carbon society will remain only a dream if we fail to develop technologies and the means for economic growth to be uncompromised by the pursuit of environmental objectives. The development of clean technology has become a prime focus of Finland and the country is trying to become a key player in the industry. Finland is one of the world's leading countries when it comes to R & D in the area of energy and environment. Despite being a small country, its share in the global cleantech market is over 1%, more than twice of its contribution to the global GDP [111]. According to Cleantech Finland, the combined turnover of the industry was over $25 billion in 2012, an increase of 15% on the preceding year [112]. The sector has roughly 50,000 employees and is expected to create 40,000 new jobs by the year 2020.

Cleantech is a relatively broad field, including companies of diverse nature that in one way or another are associated with environmentally friendly technologies [113,114]. Among these, renewable energy companies accounts for the highest percentage [115]. Table 1 and

Table 1
Top ten Finnish Cleantech Companies.

Top Ten Finnish Cleantech Companies
Wartsila
Mesto
Neste Oil
Outotec
Kemira
YIT
ABB
Kuusakoski
Outokumpu
Cargotec

Table 2
Top ten Finnish Cleantech Markets.

Top Ten Markets for Finnish Cleantech Companies
China
Russia
Germany
Sweden
Brazil
India
USA
UK
France
EU

Table 2 present the list of leading Finnish companies engaged in cleantech business, along with the top ten markets [111].

Though the country has achieved reasonable success, Finland's existing share in the international market is considered insignificant compared to its potential. The Cleantech group has evaluated countries based on different innovation drivers and has ranked Finland among the leading countries. The study reveals that the country scores extraordinarily highly when it comes to the innovation input, public R & D and innovation culture, while its score is low in commercialization, lagging behind many of the member European countries [116]. The following section briefly highlights the factors influencing the commercialization of RETs in Finland.

5. Commercialization of renewable energy technologies in Finland

5.1. Market dynamics

Market dynamics play an important role in the development of the RETs market in Finland. Finland has long held the image of an environmentally friendly country. The concerns of climate change and the need to develop cleaner sources of energy generation worldwide have provided an opportunity for a country like Finland, which has a history in the development and innovation of technologically advanced products and services, strong technological know-how and an established infrastructure suitable for becoming a key player in the industry. In addition, the recent economic meltdown and the decline of the information and communication technology (ICT) sector have triggered the inevitability of the development of a sector that can serve as the backbone of the economy in the years to come. Considering the growth potential and the urgent need, the government has started taking the initiative in order to develop the sector as a priority [117]. However, one of the key challenges the sector is facing is the bottleneck in the domestic market.

Finland is a developed country, with a small domestic market where energy is affluently available to the public. In developing countries, renewables are perceived as a vital source of energy generation for meeting basic requirements, as a sizeable portion of the population lives in villages and rural areas, far from the population centres and with very limited access to the electricity grid [118]. On the other hand, in a country with a developed energy infrastructure, the incorporation of sustainable energy technologies has emerged more due to the concerns of energy security, gaining economic benefits, improving the environment and the effective utilization of indigenous resources. The fundamental principle of economics applies here: the product will only make ground if the demand exists. In the first scenario, the demand is obvious and clear. However, when it comes to the countries that have an established energy network, RETs, in most cases, are regarded as an alternative to the conventional means of generation, more often than not an expensive one, requiring changes in the established infrastructure and consumption behaviours, and in such cases, commercialization becomes somewhat tactical as the demand for the technology needs to be developed.

This issue can be dealt with on two fronts. Firstly, the use of sustainable energy technologies can be supported and encouraged at the domestic level by developing the necessary measures and policies to encourage their adoption. Secondly, the right level of support can be provided to the companies in the internationalization process. The analysis of Finnish cleantech industries shows that the sector is dominated by small- and medium-sized enterprises. As shown in Fig. 3, approximately 68% of Finnish cleantech companies are either micro-organizations or SMEs, having fewer than 250 employees [115]. The SMEs are characterized by good market understanding, technological know-how and a forward-looking mind-set; however, they usually lack resources and an understanding of internationalization [119,120], which makes their survival difficult in a country where the domestic market is small and competitive. The government has established a number of programmes and initiatives that are aimed at developing companies' abilities to internationalize their operations [121,122]. The ultimate growth and success of the sector lie in the ability to cater global markets. Support and assistance shall continue and an attempt should be made to assist a larger number of companies in their international endeavours. The managing director of the technology centre stated:

> *"The long-term survival and potential to grow lies in the markets that are far from here and are very different fundamentally. Therefore, the support is pivotal to encourage companies to go international and avoid failures."*

5.2. Availability of financing

As discussed in the previous section, the cleantech industry in Finland is dominated by the small- and medium-sized enterprises. Due to the resource constraints, the firms often require additional funding to transform their inventions into great innovations. According to Greene et al. financing works as oxygen for the companies, as it is essential to keep them operational [123]. Finland's research and

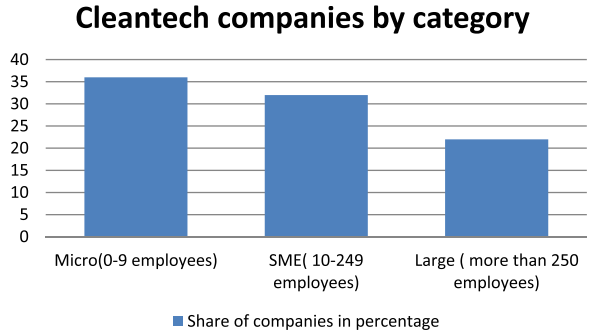

Fig. 3. Cleantech companies by category.

development budget is among the highest compared with similar economies [116]. The monetary support from the state-based institutions has helped a number of companies in meeting their financial needs. However, the access to capital, in general, is seen as a great concern, especially for the companies looking to acquire financing during the later stages of product development. A significant amount of money is required at the early stage (research and development) and the middle phase, when the product is set to be launched in the market (commercial stage). The majority of funding from state-based financial institutions is directed towards the companies undertaking R & D tasks and the companies seeking resources for the market launch often struggle to obtain financing [112], as stated by the chief financial officer of a company:

> *"If one has a prototype ready and [the] company is planning to get the product to the market, seeking financing at this stage is almost impossible. If you will ask them [state governed financing institutions] for funding, you can only expect a rejection."*

There is a need to develop special financial mechanisms to meet the financial needs of the companies that have gone through the research and development phase and are planning to get their technologies to market. A business advisor of a regional development organization echoed the concerns:

> *"The financing is offered to the companies that are involved in the research and development. We should have more financing instruments at our disposal, for the commercialization phase, as most of the companies struggle to obtain [the] funding required to efficiently launch their product in the market."*

Furthermore, the existing structure and system of support is also believed to be somewhat complex as identifying the right agency and suitable instruments sometimes becomes challenging [124,125]. According to Cleantech Finland, 58% of the firms have encountered problems with public financing. A number of different public institutes are engaged in providing financing to the firms and the process can be tiresome, as there are a number of administrative and lengthy procedures involved in the process [125]. It may be more efficient if the support for the start-up is centralized in one place and the financing is provided at once.

To this end, the opportunities for getting investments from the private sector and venture capitalists are also very stringent. The ventures specifically investing in the cleantech sector are limited in number, which puts further pressure on the public sector to provide the financial support. The future growth of the sector will be very much reliant on the firms' ability to obtain financing from the private sector. According to the assessment of Ministry of Economic Affairs and Employment, it is anticipated that 54% of all the growth-oriented SMEs will require funding during the year 2017, which further puts pressure on the government to find means and financial instruments to bridge the gap [126].

5.3. Skilled personnel

The success of a business venture is dependent upon both technological competence and managerial expertise. The studies have shown that despite having superior technology, a product may underperform in comparison with those that are technologically less distinctive but have been managed and presented to the market in a proficient manner [9,11]. The tradition of technological expertise and developing innovative products runs deep in the Finnish customs [127]. The majority of start-ups and SMEs we studied were incorporated by individuals who had a strong technical background and experience of working in the Finnish tech industry. The opportunity to provide solutions to the industry's existing problems has encouraged them to develop the technology. However, the expertise of professionals in management and marketing is rarely sought. The core team typically comprises technical experts, whose focus is almost entirely on the technology development aspect and less on how efficiently it can be presented to the target market. A number of studies have shown that Finnish tech companies lag behind in non-technical skills, especially the sales and marketing of technical products, which makes their commercialization difficult [128,129]. The managing partner of a venture capital firm said:

> *"These entrepreneurs often imagine that the product will sell itself, if it has a value, which is often not the case in real competitive world. We have seen companies fail just because they were not able to reach to their customer[s] and present their products in the manner they should have, mostly because they did not have anyone who was specialized in doing so."*

Involvement of expert personnel from different backgrounds will help companies to understand the complexities and devise strategies that are more practical and address real issues.

5.4. The role of energy policies

As discussed in Section 1.1, the RETs are competing with mature technologies that have gone through the development cycle and offer relatively better value when it comes to the price and ease of use. A number of studies have shown that the adoption of clean technologies is subject to the right set of policies and governmental support schemes [130,131]. It is often claimed that subsidies and support schemes will only be required until the industry develops the technology and means that can sustain the market on its own. A comparison of the energy generation costs of the RETs with the conventional sources in Finland leads us to the fact that there may still be some time before the renewable energy market can be driven by the market fundamentals of demand and supply. In the existing scenario, if only the market forces are to be relied on, the diffusion of RETs may remain hindered. The supportive role of the forward-looking energy policies in the development of the Finnish clean technology market cannot be overlooked. The country has achieved reasonable success in realizing its vision of becoming market leader by devising the right policies and measures to support the development. However, at times, the lack of a long-term approach and consistency in the policies has raised concerns of the players involved in the sector. The chief executive officer of a company operating in the wind sector said:

> *".....having feed-in tariff[s] in place has encouraged the companies to get into this business of wind energy. Now that they [the government] have started considering revision of the limits [referring to the government's plan of reducing the predetermined quota of 2500 MVA to 2000 MVA], what impacts do they [the government] think it will have, except discouraging investors. These sorts of things should be settled before the policies are formulated."*

The perception that policies may change in a relatively short span of time can raise concerns in the minds of entrepreneurs and technology developers about the future of the industry. In order to encourage development, the industry should be given continuous support and confidence. The growth potential of technologies such as solar or wind is tied to the government's ability to maintain favourable conditions by having the right policies in place. According to Finish Energy Industries, the long-term success and growth of the industry lies in consistent energy policies, as the energy sector requires a lot of capital, and investments cannot be encouraged without having a stable and predictable environment [109].

5.5. Nature of risk within a firm

In addition to the financing (Section 5.2), market dynamics (Section 5.1) and consistent policies (Section 5.4), the culture and psychology of the individuals in the society as a whole and within a company play a

pivotal role in entrepreneurial success and the expansion of the business ventures [132]. The firms' appetite to take risks and explore new avenues increases the chances of getting more out of the existing market or out of a new market that it is about to explore. According to Lee and Peterson, the firm's ability to undertake risk comes from a number of factors, such as experience, behaviour, the individual's psyche, society and the environment [133]. It has been observed that the culture of Finnish companies is somewhat conservative. The companies feel satisfied if they achieve moderate growth and do not bother much about expansion. SITRA has emphasized that Finnish business culture should develop and learn from the bold and risk-taking initiatives often pursued by firms operating in the United States or Israel [134]. An international business advisor working in a technology centre also affirmed the statement:

> *"We have found many of the entrepreneurs to be risk averse and avoiding making bold decisions. The companies often find themselves trapped in their conservative mind-set, depriving them from the real growth."*

5.6. Level of public awareness

As discussed earlier, the need for RETs in Finland has arisen more because of the environmental and energy security concerns than because of the value alone that such technology brings. To this end, the additional cost of using these technologies is one of the biggest obstacles to their adoption. According to Dodds et al. the price of a product is determined by the value and perceived benefits it has in the mind of a customer [135]. In order to make people pay relatively higher prices for a technology, there is a need to increase the level of awareness among people. The awareness can be increased by addressing the benefits of the clean technologies, both for the economy and environment, to the extent where the benefits justify the additional cost to the consumer of the product. Generally, the awareness of the need for improved environmental conditions exists in Finnish society. A study conducted by Moula et al. on the social acceptability of renewable energy technologies in Finland reflects that people, in general, have positive tendencies towards the environment and the adoption of renewable energy technologies [136]. This is iterated by a household customer:

> *"...of course, it is everyone's responsibility to use the cleaner sources of energy generation. Solar, wind or any other forms of green energy [ies] are definitely better than coal as they do not pollute the air we breathe in."*

However, a small percentage of the population is willing to pay extra for clean products that offer similar value to conventional technology but have positive environmental impacts [136]. There is a need to raise the level of awareness to a point where the willingness to pay for the environmentally friendly products equals the cost of energy generation using renewable energy technologies, thus making it competitive with the conventional means of energy generation (Fig. 4).

5.7. Infrastructure support

Infrastructure support is vital for smaller companies attempting to establish themselves as a successful business venture. The establishment of incubation facilities for start-ups, accelerator programmes, private and public research institutes, and facility parks can assist companies on multiple fronts. A country like Finland, which has good technical expertise, a culture of innovation and a network of universities offering sound technical education, can further foster the sector's performance by improving facilities that can help the firms to reduce operating expenses, gain expert opinions, managerial expertise and assistance in exploring new avenues. The chief executive officer of a company engaged in biomass energy generation technologies stated that:

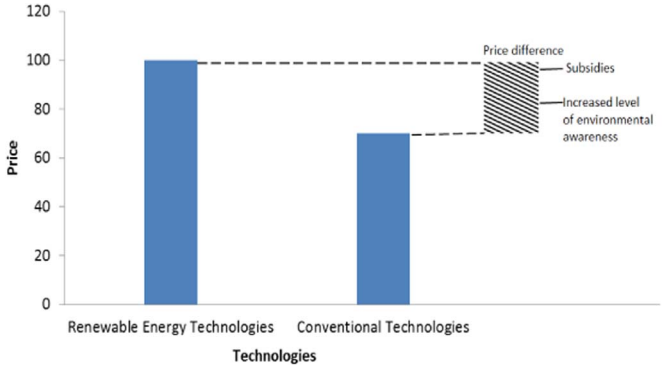

Fig. 4. Environmental awareness and willingness to pay.

> *"The expert advice we got [from Science Park] not only improved the technology a great deal, but also helped us in developing [the] company's business model and marketing plan. The combination of [these] things helped us in obtaining funding, as our proposal was practical, comprehensive and market-oriented."*

The rising number of cleantech companies and dominance of small- and medium-sized companies in the sector [122] will certainly require support from the network. The existing structure may not be enough and there is a need to develop more of such facilities to increase the level of success.

5.8. Market-oriented technology development

For a technology to become successful, it is important to have a value proposition that makes it unique and valuable in the eyes of the customer. The offering could possibly be in the form of a product's ability to deliver a value-added feature in terms of efficiency, productivity or performance. A technology may offer an excellent solution to an existing problem or have a positive environmental impact, but if it is not commercially viable, i.e., it does not match the customer's willingness to pay for it, the probability of failure increases. Such technologies also remain unable to gain the investors' confidence, as people only tend to invest in the projects that are likely to yield a reasonable return on the investments. In Finland, a number of products could not gain a market share, as the entrepreneurs failed to consider the commerciality aspects. The problem could be observed particularly in the cases where companies do not value the customers' feedback during the product development phase. The managing partner of a venture capital firm, who has assisted a number of ventures in their efforts of becoming successful, stated:

> *"If you ask me about one major reason of why companies fail to develop [a] market for their products is that they do not take [the] right measures during the development stage. How can a product or technology get acclaim, if the development of the product is undertaken in isolation, without discussion, having a feedback from the potential customers, and integrating aspects, they [customers] needed the most? This is something we discourage the most. We want products to be sold as soon as they get to the market. Only then we can ensure return on the risky investments we make. The first thing we probe while discussing the investment is why they [companies] think that customers will pay for their technology. We get so many enthusiastic entrepreneurs often emphasizing the great deal of environmental benefits their technology can offer. It really surprises us when we have to dig deep to get an idea if the commercial aspects are considered."*

5.9. Cleantech clusters

To accelerate the commercialization of clean technologies in

Finland, it is of immense importance to have a higher level of coherence between the industry, government, research institutions and other stakeholders [111]. Considering the domestic market bottleneck (Section 5.1), the state and municipalities should play a proactive role by adopting innovative technologies. This step will encourage entrepreneurs as well as providing a stage on which to demonstrate local inventions [117]. Furthermore, the measure will not only test and transform the product, but will also work as a real-time showcase for the companies to demonstrate their products to international clients and interested parties and market them [119]. Likewise, it may help companies to increase collaboration within the industry as well as finding international partners. The Finnish cluster programme has attained worldwide acclaim and ranks among the best in the world [137]. The government has supported development activities in the regions of Kupio, Oulu, Lahoti and Uusimma. The collaboration between the cluster participants has earned reasonable success by developing a number of innovative solutions [138]. The programme has assisted companies in exploring new business opportunities and promoting business in domestic markets as well as providing support for internationalization. Special measures are taken to assist companies in being successful in the growing markets such as the US, India, Russia and China [117,139], as affirmed by the director of a solar company which has recently expanded its operations in the international market:

> *"The cluster programme has helped us to expand our operations in [the] international markets in a proficient manner. We were given practical advice, training and [the] opportunity to get in touch with [the] right connections. The results are encouraging: we have generated more jobs, higher revenues and strong international references."*

5.10. Legal structure

The overall legal structure in Finland is supportive for the industry. According to Global Entrepreneurship Monitor, Finland has performed better than its peers when it comes to governmental support for entrepreneurship activities, start-ups and expansion of businesses. The regulatory environment is perceived to be stable and suitable for the business [140], as discussed by the assistant professor in the industrial engineering department of a Finnish university:

> *"The supportive legislation and policy frameworks have paved the way for development. Our [Finland's] image of being a stable democracy [with a] rule of law and conducive business environment has presented us [Finland] as a country to invest in and deal with."*

The overall structure is found to be supportive. However, when it comes to licensing a technology, the process is quite lengthy, involving a number of steps and procedures that can possibly be eliminated [112]. Improving the legal structure will further assist companies to accelerate the commercialization of green technologies.

5.11. Collaboration between academia and industry

In an industry that is abrupt, evolving and resource-intensive, in which innovations may be short-lived, it is imperative for the companies to have the right mix of resources and competencies to survive [141]. Through collaboration, a firm can share its resources and expertise, can achieve economies of scale, enhance product value and gain access to new markets and technologies [120]. The small- and medium-sized companies should constantly explore the opportunities to collaborate, not only in their own industry but also with the firms operating in the adjacent market in order to avoid direct competition and to gain benefits from the cooperation. Finnish companies generally have a good level of trust among themselves and collaboration can achieve reasonably decent outcomes [51,142,143]. The desire to have a successful footing in the global market and to negotiate the barriers to internationalization can be addressed through collaboration. According to an international business professor:

> *"The need to collaborate is greater now than it probably ever was. The success in international markets is dependent on the establishment of [the] right links and connection[s] with partners. The companies that have achieved success in their international endeavours can support others [Finnish firms] to collaborate [with international partners] and use the already established links, as the trust is already established and connections are strong."*

Such collaboration can speed up the process, reduce costs, resolve trust issues and compensate for the lack of internationalization experience by providing the necessary information and support for companies to globalize their operations. Similarly, collaboration between universities and industry can play a vital role in the development of energy technologies. Interaction between education establishments and industries can not only provide vital resources to the companies, in the form of human capital and knowledge that can be useful in improving the technical aspects of a technology, but also can offer infrastructural support and make the overall process more efficient. Our analysis shows that the collaboration between universities and industry should be developed further to gain benefits from educational establishments.

6. Discussion

The previous section has briefly discussed the factors influencing the commercialization of renewable energy technologies in Finland. Despite the fact that factors are quite diverse, an attempt has been made to categorize them according to the following headings: firm specific, market centric and policy related. Core competencies, size of the company, resources, expertise and the risk nature of the company are included in the firm specific factors. The issues can be resolved by encouraging collaboration among the companies, developing strong financial institutions, providing infrastructural support, developing clusters, assistance in exploring markets and internationalization. The market centric factors include the disruptive nature of industry, size of the domestic market, infrastructural support, skilled personnel and public awareness and consciousness about the environment. These issues can be resolved by establishing specialized institutes for start-ups and small-sized organizations, working closely with the companies to provide the expertise and resources they require, and by providing assistance and guidance about the internationalization. The policy related factors encompass subsidies and support schemes, a supportive legal framework and measures that encourage companies to invest in the clean technologies. The problems can be addressed by devising policies and support programmes to increase the renewable energy technologies' competitiveness with the traditional technologies. In addition, the legal structure should be supportive and ought not to discourage companies. The government can play a proactive role by encouraging municipalities and government institutions to prefer RETs solutions and encourage their adoption (Fig. 5).

6.1. Proposition

As discussed earlier, commercialization is a complex and multifarious phenomenon and firms should be tactical when devising their commercialization strategies. Findings from the study suggest that successful commercialization is dependent on a number of factors and it would be unwise to expect that focusing on either one can lead to the successful achievement of objectives. Therefore, it is recommended that a firm should gain proficiency at the first step before leaping on to the next. A proficient initial stride would enable a firm to reach the next phase by capitalizing on the proficiencies gained in the preceding level.

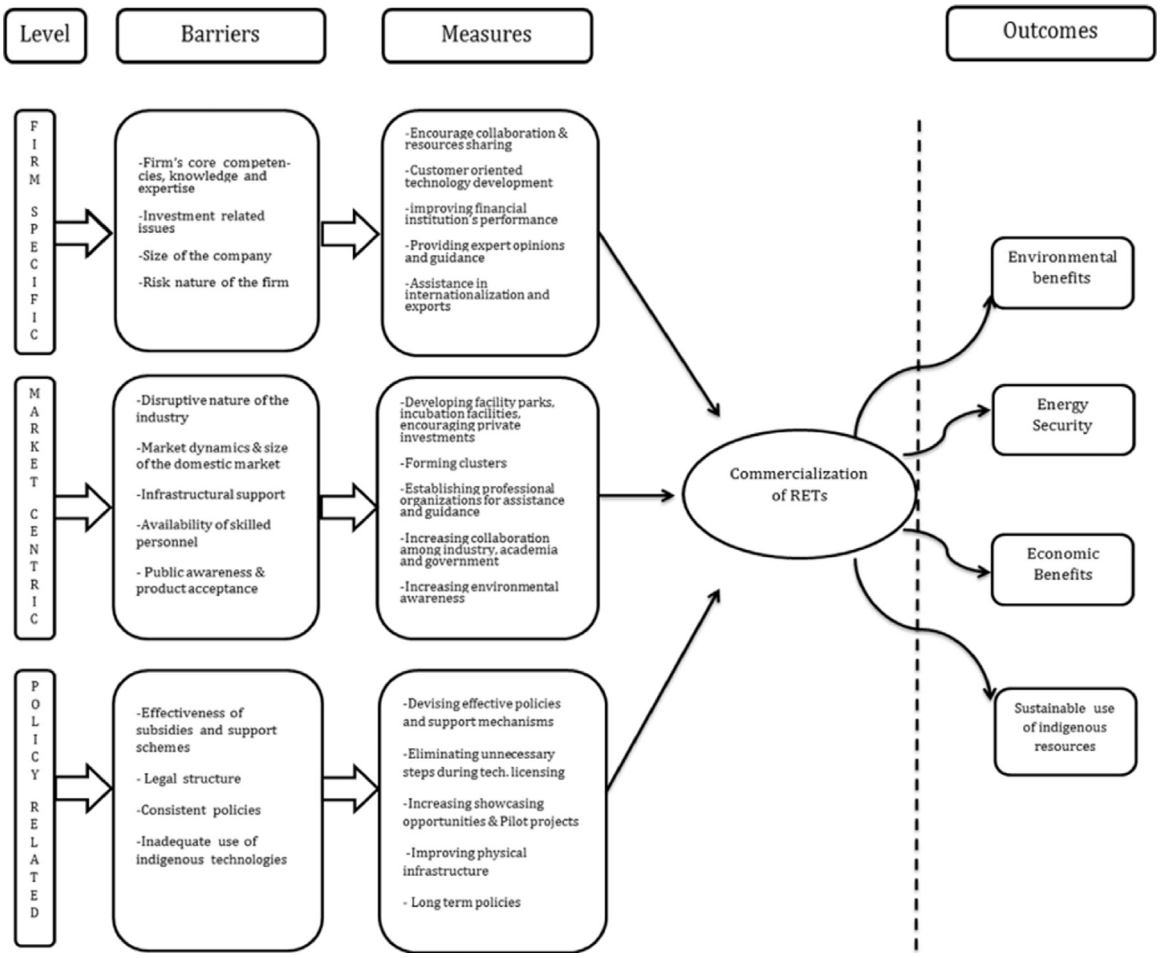

Fig. 5. Framework for the Commercialization of RETs in Finland.

The concept is very similar to a ladder, in that the process of reaching the top begins with the first footstep, striding on to the next and continuing until the destination is reached. A step-by-step approach ensures a smooth progression from the ground to the highest level, reducing the probability of stumbling.

Based on the findings, the study suggests that the fundamental step for a company is to ensure they have a strong knowledge base, the expertise and the resources required to develop a technology. The subsequent stage is to have the right level of infrastructural support available, especially for the start-ups, spin offs and small- to medium-sized enterprises operating in the industry. The support in the form of facility parks, incubation facilities and professional organizations where expert opinion is readily available can compensate for their limited resources. The third most important phase in the process is acquiring financing. The RETs industry is resource-intensive and requires substantial amounts of money in the earlier stages of development. The financing can either be obtained from public bodies or from private investors. The probability of gaining investors' interest increases once the firm has successfully acquired technical expertise and has a clear plan for development. Likewise, a key step is to have the right level of customer involvement throughout the technology development process. A number of technologies have either failed to gain customers' attention or have underperformed because the company did not seek customers' feedback during the development phase. The technology that is developed based on the team's own assumptions lacks the features that customers may value. This step will help companies to develop a technology that can better serve the needs of their target market. The last stage in the process is to have the right level of public awareness and acceptance in the market. This step is essential because, as of now, most RETs lag behind when it comes to the price comparison with the conventional technologies. The stakeholders involved in the process should play their part in spreading awareness and encouraging society to value the technology's environmental offering. The external elements, such as policies and governmental support in the form of subsidies and different support mechanisms, also play a critical role in the commercialization of RETs, as without these most of the RETs may not able to hold the ground (Fig. 6).

It is important to mention here that a number of steps could be added or removed from the list. The structure and significance of the steps varies, depending upon: the firm's size, resources, level of expertise, image of the company, understanding of the market, and connections, both at the national and international levels. The steps are not universal, and are devised considering the needs of small- and medium-sized companies; therefore, some of the phases, for instance the infrastructural support and financing, may not be effective in the case of large-sized enterprises.

7. Limitations of the study

The article presents an overall picture of the industry by exploring the factors influencing the commercialization of RETs, as a whole, in Finland. However, the technologies actually differ greatly in nature, use and development phases, and thus have distinct challenges. In this study, an attempt is made to identify the key factors affecting different technologies and to present a holistic view of the sector. Henceforth, the findings may not be applicable to one specific technology. An in-depth study shall be conducted for each of the technologies in order to explore the factors

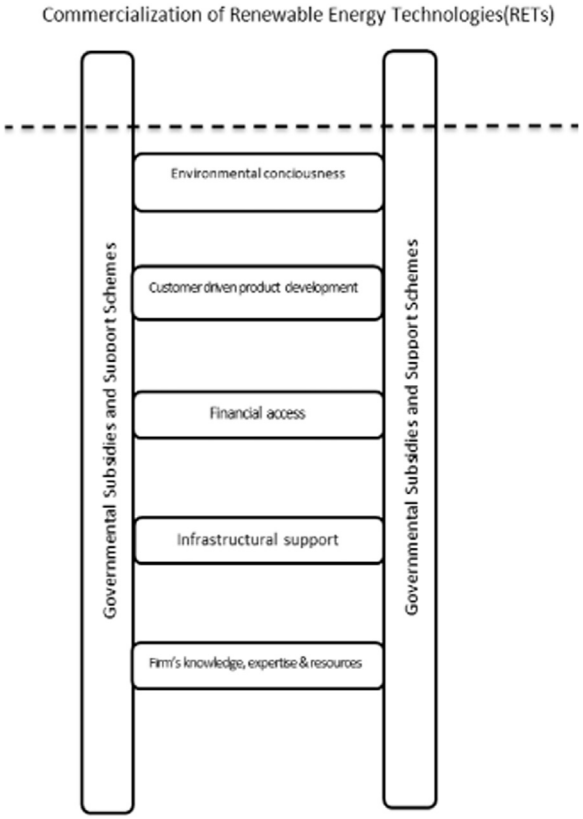

Fig. 6. Commercialization Ladder.

affecting their commercialization process. Moreover, the current study has been conducted in the Finland, where the market dynamics, technology development and business environment are different from other countries. Therefore, the findings of the study may not be generalizable in the broader context and to other parts of the world.

8. Conclusion

Finland's technological excellence, energy security concerns, sizeable renewable energy resources, research and development culture, and the emerging demand for clean energy solutions worldwide make the cleantech sector a natural choice. The government has stated its interest in promoting the sector and making it the engine of the economy. To this end, the country has achieved reasonable success in technology development aspects. However, the commercialization of these technologies has remained problematic. The objective of this study was to investigate how different RETs can be effectively commercialized in Finland. This research tried to address the question by exploring the drivers and barriers affecting the process of commercialization. The study shows that the factors driving the sector are market dynamics, strong research and development infrastructure, technological know-how, environmental awareness and supportive public policies. However, there are number of challenges the country needs to address if it really wants to attain its vision of becoming the sector's market leader. It is recommended that the key to success lies in improving financial mechanisms, encouraging collaboration, providing support in internationalization and developing infrastructural facilities for the industry. Based on the findings, the study presents a comprehensive framework for the commercialization of RETs in Finland.

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