Letter from Academia

Cleantech: Prospects and Challenges

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Abstract

The issue of climate change, greenhouse gas emissions, global warming, and their effect on nature and the ecosystem has raised serious concerns. The desire to sustain economic growth and development while keeping a check on the environmental footprints is one of the leading challenges the contemporary world is currently facing. To ensure sustained growth, there is a need for technologies and solutions that has the potential to meet industrial needs without compromising the environment. Cleantech offers a possibility to address these needs in a sustainable and environmentally friendly manner. Cleantech, being an umbrella term, is often confused and misunderstood, in terms of its definition and scope. This study seeks to explore what cleantech actually is, how this sector came into prominence, what are the driving factors behind its surge, and what kind of socio-economic, technical, and regulatory prerequisites are necessary for the advancement of this sector.

Keywords: Cleantech, Socio-economic, Technical, Regulatory, Emergence, Diffusion, Ecosystem, Drivers, Barriers.

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1 Cleantech – An umbrella term

The unprecedented growth and development of technologies emphasising cleaner aspects – often referred to as *cleantech* – offer a great deal of opportunities and challenges for business across the globe. The term *cleantech* is a compound formed of the words 'clean' and 'technology'. 'Clean' here refers to the characteristic of having relatively little or no environmental footprints, whereas 'tech', short from 'technology', refers to the apparatus through which the cleaner outcomes can be achieved. Cleantech is a relatively new term and its early use can be traced back to the mid-1990s by North America's venture capital community (O'Rourke, 2009). However, it was not until the early 2000s that the term started to appear relatively regularly in the mainstream media, sessions, and conferences (Caprotti, 2012). Traditionally, *cleantech* was often used to refer to businesses that are cleaner in nature compared to the alternatives or their predecessors. The term became a buzzword and, with the passage of time, sequentially transcended into what today is known as the cleantech sector. Since its early use, *cleantech* as a sector has seen enormous growth. Smart Prosperity Institutes estimates that the global investment will surpass 2.5 trillion dollars by the end of 2022 (SPI, 2018). Not been around for long and yet becoming one of the key sectors in today's global economy, leads us to ask what cleantech actually is, what makes it important, and what are the driving factors behind its surge.

A review of the literature reveals that *cleantech* has been defined in numerous ways. Pernick and Wilder (2007) define *cleantech* as "any product, service, or process that delivers value using limited or zero non-renewable resources and/or creates significantly less waste than conventional offerings".

Shakeel and Juszczyk (2019) explain *cleantech* as "technologies, products or services that seek to lower the negative environmental impact by bringing efficiencies, reducing waste, encouraging the use of sustainable resources and environmental protection". EU's practical guide broadly refers to *cleantech* as "any process, product, or service that reduces negative environmental impacts: through environmental protection activities, through the sustainable use of natural resources, or through the use of goods that have been specifically modified or adapted to be significantly less energy -or resource- intensive than the industry standard" (EU, 2020b). These definitions are a little different from one another in terms of scope. However, they address more or less the same entity, which is a technology (here the word *technology* refers to technologies, products, materials, processes, business models, or any related activities or systems) that helps to achieve *cleaner* outcomes (i.e. having minimal or comparatively little impact on the environment).

Following the specification above, any products, technologies, services, processes, or related activities can be covered under the umbrella of *cleantech*, if they comply with the aforementioned criteria – irrespective of the nature, scope or the sector it belongs to. According to Cleantech Group, *cleantech* covers companies operating in different sectors including energy & power, resources & environment, transportation & logistics, agriculture & food, enabling technologies, and material & chemicals (Cleantech Group, 2021).

It is important to note that *cleantech*, as is often assumed, is not a new sector that has emerged with its own set of technologies. Rather, many of the technologies currently attributed to the cleantech sector have been around for decades, well before the term *cleantech* became popular. These technologies have been labelled differently[1] in the past, however, none has been able to gain the legitimisation and the support that *cleantech* has as a 'distinctive sectoral identity' (Caprotti, 2012). The fact that *cleantech* is a broad and general term used for a wide variety of technologies spanned across different sectors actually makes it challenging to specify what constitutes cleantech and which technologies should be included or excluded from the list. Hence, there are a number of limitations that should be considered while classifying cleantech (O'Rourke, 2009).

Cleaner application and use

The first limitation is concerning the scope of the technology's application. To date, a wide majority of products are deemed clean and thus labelled as *cleantech*, based on their use, which in actuality is only one aspect of the technology life cycle[2]. How technologies were produced and disposed of, whether the principles of cleaner production were also adopted during other phases of life cycle, apparently remains out of the scope. For instance, a technology used for harnessing a renewable energy source can be labelled as *cleantech* as it produces energy with zero or minimal emissions. However, how the technology was manufactured in the first place, what materials were used, whether the company's operations and processes also adhered to the principles of cleanliness are hardly considered. Similarly, once a technology reaches the end of its life cycle, considerations to whether there were mechanisms in place to ensure it is recycled or disposed in an environmentally friendly manner are rare. The current definitions, more often than not, considers the 'use' aspect as a primary criterion for establishing whether it is cleantech or not, which can be argued to be a narrow approach.

A further challenge linked to this perspective is the varied application of these clean technologies. A technology may play a key role in achieving a cleaner outcome in one context, however, applying the same in a different setup may produce different results. For instance, a company producing

1. such as renewable energy technologies, green technologies, green tech, environmentally friendly technologies, sustainable technologies, and so on, some of which are still in used.

2. A life cycle includes different stages such as extraction of raw material, manufacturing, logistics, utilisation and disposal.

microchips that are used in renewable energy systems can be categorised as a cleantech. However, if the same solutions are also applied in a coal industry context, it would not make it so clean. The lack of information about the context of applications and the difficulty of keeping track are some of the challenges that make categorisation troublesome.

Cleaner outcomes

The second issue is related to technologies' real impact. In actuality, it is hard to determine when a technology can be referred to as a *cleantech*, as there are no such criteria, no benchmark or threshold that the technology should match in order to be included in the group of clean technologies. Currently, a technology is considered as *cleantech* if it is 'cleaner' in use compared to the incumbent technologies. According to this logic, the technology in question needs to perform better than the dirtiest alternative currently available (which is a baseline). This makes the categorisation difficult as the actual impact may vary based on the nature, scope, and the current state of the sector.

It is therefore advised that above-mentioned factors should be considered, where possible, when classifying cleantech.

2 The emergence of cleantech

Cleantech differentiates itself with competing technologies based on a distinctively unique value offering, i.e. protection of the environment. The traditional model of development relied on the technologies and means to support economic development and growth. The approach has brought us far, however, fundamental issues such as uncontrolled production and consumption patterns have made it impossible to continue in a similar manner (EPA, 2019; Shakeel & Rajala, 2021). The unsustainable use of natural resources, excessive emissions, reliance on external sources, and the issue of global warming have forced us to reconsider the choices we have made in the past and adhere to the principles of sustainability and cleanliness in our operations (EU, 2018; IPCC, 2018).

Historically, the issue of environmental degradation gained prominence during the latter part of the 20^{th} century, fuelled by extreme environmental hazards, damage to the ecosystem, and the issue of climate change (IPCC, 2013; Wuebbles et al., 2017). This forced governments and policymakers across the globe to come up with a frame of references and guidelines to limit corporations and large polluters to decelerate environmental degradation. The underlying aim was to force companies to pay for their pollutions or externalities caused by businesses. However, the approach feared stagnation and deceleration of economic activities by keeping a check on industrial activities, consequently limiting economic growth. Hoffman (1999) referred to this as a trade-off leading to a win-lose situation, where advancing on one front may significantly hamper the growth of the other. Realising this challenge, the last quarter of the twentieth century experienced a transition towards more voluntary approaches where companies adopted programs to minimise pollution, emphasised on cleaner production and eco-efficiency.

The emergence of *cleantech* can be grounded into the premise that economic development and productivity should remain the centre of attention with default emphasis on the protection of the environment. Caprotti (2012) explained that both market-related and political factors can be attributed to the growth of cleantech. The huge amount of capital investments flowing in the technologies central to the sector as well as large organisations' interest in establishing units taking care of clean technologies further legitimised the sector as an investment worthy.

On the political front, the emerging discourse that the environmental challenges and issues can only be fixed by developing innovative technologies and solutions further highlighted the importance of the cleantech sector. A recent report by Cleantech Group presents that the global efforts to reduce the level of carbon emissions and reaching a net-zero target can only be made possible with the innovations made in the cleantech sector (Cleantech Group, 2020). Reaching these ambitious environmental targets would not only require existing technologies to take a leading share but also new ground-breaking innovations. According to the International Energy Agency (IEA) estimates, 50% of the technologies needed to meet the environmental targets have not yet reached the market (International Energy Agency, 2020). To address this challenge, EU has launched a fund of one billion euros dedicated to the development of cleantech in 2020 (EU, 2020a). These indicators are encouraging for businesses, investors, and other actors in the ecosystem, reiterating the fact that the sector is only going to grow with the backing of governments and international bodies, as the political drive towards a low carbon society and for finding pathways to sustainable energy transition remains a priority.

3 Socio-economic, technical and regulatory considerations

Clean technologies differentiate themselves from conventional technologies based on their positive environmental impacts (Lane, 2011). However, being environmentally friendly alone may not guarantee success. The survival and success of a new product or technology is a complex and a multifarious process requiring a number of pieces of puzzles to fit in before it can actually make a mark in the market (Cooper, 1988; Kassicieh & Radosevich, 1994). First and foremost is the functionality of the technology. In the case of cleantech, a technology should be able to perform its fundamental function at a similar or higher level of efficiency compared to conventional alternatives with the added feature of being in harmony with the environment. Moreover, these value offerings should be available at a price consumers are willing to pay. The products or services whose unique selling proposition is positive environmental impact alone often struggle to gain a foothold, as only a small fraction of the market is generally willing to pay for the environmental benefits alone (Balachandra et al., 2010). Therefore, for any cleantech solution to successfully commercialise, it is important to have a technical functionality that is valued by the customers (Shakeel, 2019).

Secondly, most of the clean technologies are disruptive in nature [3], meaning they are different from their counterparts operating in a similar sector. These technologies often come with the value offerings that are novel to the existing markets, and, therefore, had to cope up with the challenge of establishing a new set of systems, structures, and customers segments, all making their widespread adoption and diffusion somewhat challenging (Christensen et al., 2016; Woschke et al., 2017). Since the existing market structure is inherently supportive of conventional technologies, it often becomes difficult for some of the clean technologies to compete on their own. The conventional technologies, being around for decades, having gone through the cycle of developments and perfecting over time, often become customers' preferred choice, as they have the potential to serve the needs in an economical way as well and can be integrated into the existing infrastructure. For instance, renewable energy technologies can play a great role in meeting present day energy needs in a sustainable and environmentally friendly manner (REN21, 2019). However, despite their huge potential and the possibility of generating energy at relatively competitive prices[4], their actual contribution to the global energy mix remains limited (Ritchie & Roser, 2020). The

3. Disruptive innovation is a type of innovation that disrupt the existing market by offering a product of services that is novel to the market segment, and often requires changes in the existing system and infrastructure. Disruptive innovations have a potential to considerably change the outlook of the market.

4. Some of the renewable energy technologies have proven to be competitive with conventional alternatives when the right set of policies and infrastructural support are provided.

existing energy system is highly centralized, controlled by either the state or large-scale energy utility companies. A widespread adoption and diffusion of RETs cannot be achieved unless a supporting infrastructure (physical and regulatory regimes) is set in place, which requires a great deal of motivation and investments, consequently making their diffusion challenging (Shakeel et al., 2017).

Thirdly, it is observed that small and medium sized organisations are often the source of radical technologies. These companies are usually strong in technology development. However, they often struggle to mobilise the needed infrastructural, human, and financial resources required for a successful diffusion (Brown et al., 2007). Therefore, it is important to ensure that the companies can access the support needed during various phases of technology development and commercialisation. A support in the form of financial grants, loans, incubation facilities, and accelerator programs can be of assistance (Miller & Bound, 2011; Sarzynski et al., 2012; Wonglimpiyart, 2015).

Lastly, one of the most important things is the level of awareness among customers. Being environmentally friendly could only guarantee success if people value the environment and are dedicated to address this issue. There is a great need to raise the level of environmental awareness among the public (Shakeel & Rahman, 2018). A conscious effort should be made by all stakeholders involved in the process to highlight the issue of the environment, humanity's impact on the environment and ecosystem. The production and consumption patterns, that we have adopted over the years, and the impact it had in the form of increased emissions, melting of glaciers and rising sea level, extinction of species, changes in the weather patterns, frequent occurring of environmental hazards and related risks should be highlighted. Likewise, the importance of the adopting cleaner solutions, at the individual and community level, and their positive effect for the economy, the environment and society, both in the short term and long run, should be emphasised. This will not only elevate sustainable ways of living but will also stimulate the demand for clean technologies as well as will encourage customers to pay a premium for environmentally friendly and clean alternatives.

Based on the above-mentioned factors, a significant number of clean technologies struggles to survive on their own. Considering current needs and future potential, the growth and development of clean technologies cannot be left alone to the *'invisible hand of the market'*[5], where demand and supply can create equilibrium in the market. Rather, there is a need to develop a supportive structure around clean technologies that can provide the needed support and stimulus. Assistance in the form of regulations and support schemes not only help companies in the technology development but also provide support needed at the earlier phases of market launch. The supportive policies and regulatory regimes have played an important role in the development of clean technologies and have brought these to the point where they can compete with the conventional technologies on a level playing field without any kind of favour or support. Therefore, it is important that state level support, in the form of financial incentives, subsidies, and the supportive policy regime are available for cleantech companies to assist them throughout the process of technology development and diffusion. Solar photovoltaic (PV), one of the leading sources of renewable energy generation today was once deemed too expensive for use (Nemet, 2019). REN 21 report shows that currently 47 countries have at least 1 GW installed capacity compared to only 18 countries in 2009 (REN21, 2020). The wide spread diffusion of solar PV can be attributed to the improved technical functionalities, reduced cost, possibilities of integration

5. Invisible hand of market is a metaphor used by *Adam Smith,* in his famous book '*the inquiry into the nature and causes of the Wealth of Nations*' published in 1776, to explain invisible forces that drive free market

into the system – all made possible through the combination of incentives, subsidies, grants, and supportive policy and regulatory regimes (Hoppmann, 2015; Jacobsson & Lauber, 2006; Sahu, 2015; Zhang & He, 2013).

The proponent of supportive policies and financial incentives argues that such schemes will only be required until the technologies improve in terms of performance, reliability, cost and level of environmental awareness (Gross et al., 2003; Yang et al., 2020). It is also argued that the subsidies or incentives dedicated to the development of cleantech are not actually a favour but a need. The fact that a lot of pollutant technologies still get subsidies from the government, as well as get through without being charged for the pollution, gives them an undue advantage. Therefore, it becomes essential for cleantech to get the support and assistance required to compete. The successful diffusion and adoption of cleantech lie in the intersection of technology, regulatory and market related factors. Failing on any of these fronts can make the diffusion challenging.

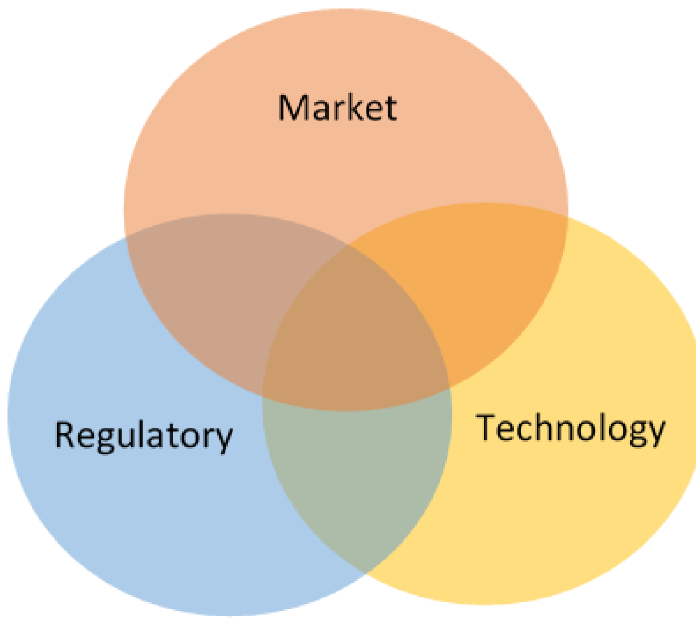

Figure 1. Successful diffusion of clean technologies.

Ecosystem thinking can help in addressing some of the issues that companies face when it comes to the development and diffusion of clean technologies. Many of the clean technologies, being in the earlier phases of development, operating in the rapidly changing and evolving business environment, relying on regulatory support, and originating from the resource stricken small and medium size companies can benefit from a close collaboration with the ecosystem actors. Through collaboration, firms can share resources, gain expertise, and the support needed to carry out the operations in efficient and effective manner. Particular attention should be paid to establishing collaboration with higher education institutions. Universities are home to innovative minds and advanced research. Collaboration with higher education institutions can provide companies with an opportunity to gain access to the resources and facilities that can help improving the overall process and efficiency(Niemi et al., 2021). An opportunity to translate results from university to industry and vice versa can be beneficial to both institutions as well as for the society at large. Research conducted by DaSilva (1998) shows the effect university-industry collaboration had in the development of the biotech sector. Lee (1996) further suggests that the potential and likelihood of collaboration is higher in technical domains. The high-tech nature of the cleantech makes it a good avenue for collaboration. However, efforts should be made to enhance the collaboration to gain fruitful results.

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